DOCUMENT RESUME

ED 194 303 SE 032 772

TITLE	Decisions for Lake Michigan: A Course on Water Quality Issues.
INSTITUTION	Purdue Univ., Hammond, Ind. Calumet Campus. Inst. for Environmental Education.
SPONS AGENCY	Office of Education (DHEW), Washington, D.C.
REPORT NO	ISBN-0-931682-11-8; LC-80-80505
PUB DATE	79
NOTE	384p.: Contains occasional light and broken type.
EDRS PRICE	MF01/PC16 Plus Postage.
DESCRIPTORS	Adult Education: *Citizen Participation: *Community Involvement: Decision Making: *Environmental Education: Environmental Standards; *Natural Resources: Physical Environment: Public Health: Water Pollution: *Water Resources
IDENTIFIERS	*Water Quality

ABSTRACT

This project's primary concern is the encouragement of citizen participation in the public decision-making processes affecting Lake Michigan. This course manual was designed to serve a dual function: (1) to provide a reference source in the form of curriculum materials for trainees admitted to the program; and (2) to document some of the most critical issues confronting Lake Michigan as seen by various authorities from both the private and public sector in the area of environmental management. (Author/BW)

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ED194303

DECISIONS FOR LAKE MICHIGAN

A COURSE ON WATER QUALITY ISSUES

U S DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

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PURDUE
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DECISIONS FOR LAKE MICHIGAN

A Course on Water Quality Issues

PURDUE
UNIVERSITY
CALUMET
Hammond, Indiana 46323

The Institute for
Environmental Education

THIS PROGRAM WAS DEVELOPED UNDER A GRANT BY THE CONTINUING EDUCATION BRANCH, OFFICE OF EDUCATION, DEPARTMENT OF HEALTH, EDUCATION AND WELFARE. 1979.

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LC 80-30505
ISBN 0-931632-11-8

TABLE OF CONTENTS

Preface / i

Introduction

Thomas D. Sherrard / ii

Natural Background

The Natural Setting
Dr. Mark Reshkin / 1

Lake Dynamics and Hydrology
Dr. Guy A. Meadows / 31

The Chemical and Biological Characteristics of Water Pollution
Dr. James Peterson and Dr. Joanne M. Westphal / 45

Lake Modeling for Decision Making
Dr. Kenneth Reckhow / 75

Political Processes and Applications

Water Quality Laws
Leighton Leighty / 95

Lake Economics
Dr. Daniel W. Bromley / 103

The Decision-Making Process and Agency Involvement
Jack Meltzer and Mary Speer / 129

Drinking Water Decisions--A Complicated Procedure
Elaine Kaplan / 173

Water Supplies and Wastewater Treatment
Dr. Joanne M. Westphal / 193

The Industrial Stake in Water Quality
Stefan Shoup / 235

Special Issues

Toxic Substances in the Great Lakes
Dr. Joseph J. Delfino / 271

Preservation of Natural Systems of Lake Michigan and the Coastal Region Communities
Paul M. Strand / 301

Shoreline Erosion
Dr. Mark Reshkin / 337

Public Participation in Great Lakes Decisions
Richard Robbins / 361

PREFACE

THE MATERIALS THAT YOU ARE ABOUT TO READ HAVE BEEN PREPARED AS PART OF THE INTERSTATE WATER QUALITY PROGRAM ENTITLED "DECISIONS FOR LAKE MICHIGAN", A HEW FUNDED PROJECT AWARDED TO PURDUE UNIVERSITY-CALUMET IN 1978 (SEE INTRODUCTION). THE MANUAL WAS DESIGNED TO SERVE A DUAL FUNCTION: 1) TO PROVIDE A REFERENCE SOURCE IN THE FORM OF CURRICULUM MATERIALS FOR TRAINEES ADMITTED TO THE PROGRAM; AND 2) TO DOCUMENT SOME OF THE MOST CRITICAL ISSUES CONFRONTING LAKE MICHIGAN AS SEEN BY VARIOUS AUTHORITIES FROM BOTH THE PRIVATE AND PUBLIC SECTOR IN THE AREA OF ENVIRONMENTAL MANAGEMENT.

THE COMPLEXITY OF THE ISSUES INVOLVED OFTEN REQUIRED THAT SOME OVERLAP OF MATERIALS OCCUR. BUT EVERY EFFORT WAS MADE TO PREVENT REDUNDANCY IN THE SUBJECT AREAS PRESENTED. THE READER SHOULD BE AWARE THAT THIS VOLUME IS BEING REEDITED AND EXPANDED AS NEW AND CRITICAL AREAS BECOME IDENTIFIED.

SPECIAL THANKS ARE EXTENDED TO THE EDITORS, WRITERS AND VARIOUS CONSULTANTS WHO CONSCIENTIOUSLY SUPPORTED THE OBJECTIVES OF THIS MANUAL THROUGH NUMEROUS REWRITINGS.

INTRODUCTION

Thomas D. Sherrard

THIS PROJECT is primarily concerned with encouraging citizen participation in the public decision-making processes affecting Lake Michigan. Citizen involvement in public decision making has received a great deal of attention during recent years. Almost all of the major congressional legislation of the past decade concerned with social and environmental matters mandates consultation with citizens--e.g., the Economic Opportunity Act (early 60's); Model Cities (mid 60's); Community Development Block Grants and Coastal Zone Management (1970's). These pieces of legislation call for citizen input. In fact, many such laws deny implementation and withhold funds if that consultation does not take place.

But it is not always a simple matter to attain meaningful citizen participation. The complexity of some of the issues, particularly in the environmental field, often discourages citizens from participating because they do not feel competent to make decisions or even to present their views. A lack of knowledge on an issue may make citizens feel that they are at the mercy of the experts. This subjugation can result in resentment and may be the reason for the reported prevalence of voter apathy, the widespread feeling that things are beyond our control, and the attitude that citizen's views do not matter in spite of the protestations of the bureaucrats to the contrary.

These same frustrations and resentments may also give rise to the reported widespread suspicion of government. There is no doubt that there is extensive objection to government involvement in private affairs. But government and regulation in public health and environmental matters is the only way we can avoid rabid exploitation by private interests of our material resources and the very environment which nurtures us. Rather than resenting and resisting governmental intercession, the citizen must find ways to influence government to choose acceptable goals and to intervene in acceptable ways.

As we see it, the ordinary citizen can only feel comfortable in exerting this influence if he is knowledgeable and informed. This does not mean that the citizen must become an expert, but it does mean that the citizen must have access to the latest and best information that is available on those issues that may affect him in significant ways and are up for public decision at any given time. It seems to us that it is the responsibility of government and its agencies to make this sort of information available to the citizen. It is an appropriate responsibility of public institutions of higher education to make sure that this kind of information is transmitted in an intelligible way and, as far as possible, in nontechnical language so that rational choices can be made by ordinary citizens. And finally, it is the responsibility of the citizen to make this influence felt after he is in possession of the facts and is familiar with the decision making system.

Why Is Lake Michigan So Important?

In a recent publication, the Great Lakes Basin Commission stated that "one of the most pressing problems facing the Great Lakes System is water quality degradation. A large part of the population and industry of the United States is dependent on this water for present use and for future growth. It is imperative that the downward trend in quality be reversed and active programs for this purpose be continued and expanded." What is true of the larger system is also true of Lake Michigan, which is the only one of the Great Lakes entirely within the boundaries of the United States. It is far and away the largest body of fresh water wholly contained in this country and is, in fact, the fifth largest fresh water lake in the world. The four states surrounding the lake; Wisconsin, Illinois, Indiana and Michigan contain 30 million people, or 15% of the 1970 population of the United States, all of whom are affected to some degree by the health of this great body of water, all 3.9 billion acre feet of it! Almost half of that number, 13.5 million people, actually live within the Lake Michigan basin and their health, well being, and in many cases, their livelihood are directly tied to the lake and its tributaries.

Again, the Great Lakes Basin Commission can be quoted, "Water pollution problems in the Great Lakes Basin can be divided into seven categories; biological imbalance, nutrient enrichment, buildup of dissolved solids, bacterial contamination, suspended solids, chemical contamination and oxygen depletion." This is a formidable array of problems indeed, and Lake Michigan is particularly prone to degradation because it lies apart from the rest of the system and its "flow through" time is very great. (It is estimated that this time is 110 years as compared with 2-1/2 years for Lake Erie!) The long residence time of water in Lake Michigan suggests the difficulty of flushing out pollution once water quality has been degraded. This means then, that pollution of this great body of water must be prevented at all costs.

Lake Michigan provides the four state area with water for domestic use; food, transportation, industry, power generation, recreation, and last but not least, it is a major aesthetic resource. It is a natural resource of incalculable value. It can only be protected and preserved if its value is completely understood, and if all the forces that effect it are also understood. Finally, it is only if the various powers involved--myriad units and levels of gover-ment, business, industry, and the public as a whole--are fully informed and working together to utilize and preserve it, can we be sure that it will be available for future generations.

The Project

The focus of this project is on Lake Michigan and the Lake Michigan Basin. When I first came to the Chicago area as a student in the early 1950's, I can recall at that time an article in one of the Sunday newspaper supplements addressing the growth potential of the Chicago Metropolitan area. In it the statement was made that one of the greatest assets of the region was the unlimited availability of pure water to meet all potential needs for human consumption and industrial uses. There was no hint then of limitation of the supply and no concern about quality. After a few years sojourn in arid Southern California, I returned to Chicago. It was now near the end of that decade and there was already talk of limits being put upon the amount of water which could be drawn from the lake. A beginning concern about the quality of water in the lake and its tributaries was being expressed. A few years later a spectacular die-off of alewives, whose smell reached a block from the beach all along the Chicago shoreline, solidified the worries and concern about the future of the lake and its basin has grown ever since.

As the environmental movement gained momentum in this country, enlightened public leaders in the midwest began to realize that the Great Lakes system was not an unlimited resource that could be taken for granted, but was in fact, an endangered resource.

In the mid-1960's, a group of faculty members at Purdue Calumet began to develop community education activities concerning the environment. The Purdue Calumet Campus is located in Hammond, Indiana in the Northwest Indiana region where environmental problems have particular salience. We found in a heavily industrialized area such as this that people had always accepted environmental degradation as an inevitable accompaniment of industrial development. We perceived that improvement could only be realized if people began to raise their expectations and eventually demanded an improved environment for themselves and their families. But as time wore on it became increasingly clear that one of the most priceless material assets of the region, Lake Michigan, was a shared asset. While much could be done locally about controlling certain aspects of environmental degradation, Indiana controlled only a few miles of the lake shoreline, and although this state contributed substantially to the lake's pollution, the maintenance of lake quality was clearly an interstate if not a national problem and responsibility. But clearly the integrity of this great national resource was endangered and we must play a significant role in dealing with it.

And so we sought in early 1977 the collaboration of the Lake Michigan Federation, a voluntary organization that bridges the arbitrary political boundaries around the lake, and simultaneously sought the support of continuing education authorities who administer Higher Education Title I funds in the 4 states bordering Lake Michigan. With their encouragement, we sent a proposal to the Community Services & Continuing Education Branch of the Office of Education in HEW which administers the discretionary grant program with funds from Title I of the Higher Education Act. That proposal was based on several fundamental assumptions.

1. That the maintenance of water quality in Lake Michigan is a matter of great national and regional importance.

2. That this goal cannot be achieved without a full measure of active citizen participation by a wise and informed public in all four states. By enhancing the individual competence of certain potentially significant actors in the environmental network that social change could be effected.

3. That public institutions of higher education have a responsibility to serve their communities and their region and by working with community organizations and associations they can multiply their effectiveness.

The project proposed to call upon the most knowledgeable academic experts in the 4 state area and with their help prepare a core curriculum for a training program for a selected group of citizens from the 4 states. Accordingly after the project was funded, a knowledgeable group of experts drawn from local universities and public administrations were brought together in the late autumn of 1977 on the shores of Lake Geneva in Southern Wisconsin. In a two-day meeting this group laid out the outline of the proposed curriculum.

It was clear from the outset that we were dealing with a very broad subject that could only be addressed from an interdisciplinary stance. And as the project has progressed this multidisciplinary aspect has only been reinforced. As the report of the Research Advisory Board of the International Joint Commission in July, 1978 stated, "Planning and management of such a priceless resource as the Great Lakes requires more than a knowledge of the chemical and physical water quality; it requires an understanding of the total ecosystem and the diverse interactions which occur within its chemical, physical, biological and societal components...the Ecosystem approach provides the philosophic basis for the view of man as part of nature. It directs the Parties and the Commission toward treatment of the patient (the Ecosystem) rather than the symptoms or disease. It relates the biological and technological activities of man to the carrying capacity of the Ecosystem, linking the human body to the biosphere." This approach accounts for the wide-ranging nature of the papers. Although the natural scientific aspects have not been neglected, we have also included historical and socio-political as well as economic points of view.

We are grateful to the Office of Education for the opportunity to perform this service to the people of these 4 states and we are grateful to the academic experts who have prepared these papers. Special thanks are due J. M. Westphal who edited and helped to coordinate all of the curriculum materials. And finally, we are indebted to the many others who have participated in this project in one way or another.

10

NATURAL BACKGROUND

MARK RESHKIN

MARK RESHKIN holds a joint appointment with the School and the Department of Geology, at Indiana University-Northwest. He teaches courses in physical geology, mineralogy, environmental geology, environmental education, and environmental administration. His research interests lie in the areas of glacial and quaternary geology in northern Indiana, environmental administration, and semi-arid geomorphology of the Northern Rocky Mountains. He is extensively involved in environmental activities, serving as a consultant to local, regional, state, and federal agencies on environmental concerns in northwest Indiana. In addition to serving as Director of the Northwest Consortium Title I grant to do environmental assessment and planning, he has been a consultant to the Indiana Senate Committee on Environment, and Principal Investigator of the Environmental Impact and Natural Resources Inventory Study of the Indiana Dunes National Lakeshore. Dr. Reshkin has previously served as Director and Associate Professor in the Division of Public and Environmental Affairs, as Director of the National Science Foundation Summer Institutes in Earth Sciences at Indiana University, and as an instructor in five other National Science Foundation Institutes. He is the author of numerous articles and publications, including Basic Ecosystem Studies of the Indiana Dunes National Lakeshore, Land Use in the Indiana Coastal Zone, and Environmental Perspectives.

His personal interests include jogging--about two miles a day--and swimming. Work at the Indiana Dunes National Lakeshore has led him to various outdoor recreation pursuits including hiking, and campfire lore.

Presently, Mark is writing a book about the Indiana Dunes area for the Indiana University Press, and is working on various historic preservation efforts in Porter County, Indiana.

GLOSSARY

CENTRAL LOWLANDS PHYSIOGRAPHIC PROVINCE: a landscape (geomorphic) division of North America stretching from the Appalachians on the east to the Great Plains on the west. The Great Lakes Section of this province contains the Lake Michigan region and is an area in which the landscape vividly reflects the effects of relatively recent glaciation.

COASTLINE: the line that forms the boundary between the land and the water.

COASTAL ZONE: the land and water area bordering the shoreline or coastline.

COASTAL ZONE MANAGEMENT ACT: Section 301 of P.L. 92-583 passed in 1972 is known as the Coastal Zone Management Act. It is intended to promote efforts to better manage coastal natural and cultural resources. Each of the states bordering Lake Michigan has undertaken efforts under this act to better plan and manage its coastal zone.

GEOLOGY: the study of the earth - a generally field-oriented applied science which focuses on the origin, structure, physical and biological processes, and natural history of the Earth.

GLACIER: a mass of ice, lying largely or entirely on land, formed by the compaction and recrystallization of snow and which flows or has flowed.

GLACIAL DRIFT: a general term for all earth materials of either direct or indirect glacial origin.

GLACIAL OUTWASH: stratified sand and gravel deposits formed by meltwaters streaming away from the margins of a glacier.

GLACIAL REGIMEN: the "budget" of a glacier reflecting the balancing of snow nourishment, ice float, and melting, and determining whether the glacier is growing or shrinking or just maintaining its size and shape.

GLACIOLOGY: study of the physics and chemistry of glacial ice.

HOLOCENE: the current epoch of the Quaternary Period, essentially, the time since the retreat from the region of the last large continental glaciers.

ICE AGES: a term generally synonomous with the Pleistocene Epoch, a time when four major continental glaciations covered much of North America. Other ice ages of continental scope occurred during the late Palezoic Era and in Precambrian time.

ICE-CONTACT LAKES: lakes formed due to the impoundment of drainage from the glacier or adjacent to it with the glacier itself serving as a giant dam. All of the Great Lakes evolved from initial, ice-contact lakes.

ISOSTATIC ADJUSTMENT: the crust of the earth can be described as "floating" on a plastic underlying unit known as the mantle. The added weight of the thick, continental glaciers depressed the crust beneath them and, with the subsequent melting of the ice and disappearance of the glaciers, the land has adjusted (isostatically adjusted) by rising. These adjustments are recognized through the tracing of the elevations of raised, younger shoreline features north of Luddington and Milwaukee.

MORAINES (END OR TERMINAL): deposits of glacial till, accumulated into a hilly topography, which were built at the margins of the glacier during a period of time when the glacier's form neither expanded or shrank. Ice flowing from source area to margin deposited the till, therefore, in a generally narrow, accurate belt known as an end or terminal moraine.

PLEISTOCENE EPOCH: the major portion of the Quaternary Period, also known as the "Ice Ages". The Pleistocene began approximately two million years ago and ended with deglaciation in the Lake Michigan region some 10,000 years ago.

QUATERNARY PERIOD: the most recent period of the Cenogoic Era; it is comprised of the Pleistocene and Holocene Epochs.

RADIOCARBON DATING: a radioactive form of Carbon (C^{14}) is produced in the upper atmosphere by neutron bombardment of Nitrogen (N^{14}). The C^{14} combines with Oxygen photosynthesis and the food chain, C^{14} is taken into organic systems and maintained in its platine proportion to the more common carbon isotope (C^{12}) while the organism lives. When the living matter dies, the C^{14} decays naturally at a known rate (a half-life of 5,730 years) and age determinations of the decay period can be made. This has been used as a mechanism to place absolute dates on recent geologic events.

SEDIMENTARY ROCKS: secondary or (for the most part) derived rocks formed when sediments accumulate in depositional environments at the earth's surface. These sediments become lithified as the result of compression (from the weight of overlying sediments) and natural cementation.

SNOWLINE: the lower limit (elevation) of perrenial snow. Below this elevation, the snow accumulating in the winter, melts away in the summer. Above this elevation is the zone in which snow can accumulate eventually leading to formation of a glacier.

TILL: unstratified glacial sediments deposited directly by ice and consisting of clay, sand, gravel, and boulders intermingles in any proportion.

WISCONSINAN AGE: the most recent major glaciation to cover the Lake Michigan region.

THE NATURAL SETTING

Although the Earth is at least 4.5 billion years old, it is clearly the geologic events of only the last several thousands of years that have created the present landscape in the Lake Michigan region. This chapter emphasizes the Ice Age events of glaciation and the formation of Lake Michigan and the resultant land forms, primarily, sand dunes, cliffs, beaches, and other shoreline features bordering the Lake. A brief mention of pre-glacial geologic events is included to reveal evidences of an ancient geologic history that goes back a billion years. However, the discussion treats primarily the physical evolution of the "Ice Ages" and attempts to explain the geologic processes that have produced the landscape around Lake Michigan as we know it today.

Geology, the study of the planet Earth, is concerned with the planet's origin, its material composition and structure, its history, including the evolution of life and the multitude of physical and biological processes which have acted and continue to act on it. Geology draws heavily from a wide variety of sciences--that is, it is a multidisciplinary science. Geology has long been recognized for its applied aspects.

Mineral extraction, water resources and the location of energy fuels have, for a long time, dominated the interests of geology. Lately, however, geologists have expended their focus to include the proper use of the land and water related to our ever increasing ability to alter the natural landscape by creating roads, dams, harbors, industries, indeed, whole cities.

This chapter seeks to convey an appreciation of the vastness of the geologic history of the Lake Michigan Region with emphasis on the recent natural processes and human activities which have impacted on the landscape.

As Jack L. Hough said in his book, The Geology of the Great Lakes:[1]

> "...the location of the Great Lakes and many details of their topography are closely related to the type of rock and to the structural framework of the region. It has been pointed out that the Great Lakes are known to have existed for about 20,000 years, and this period dates from the time when a continental ice sheet, which had covered all of the lake basins, first shrank back from the southern divides and allowed water to accumulate between the divides and the glacial fronts. The basins themselves have been excavated in certain zones, generally coinciding with the outcrop belts of the less resistant rocks. The detailed history of the formation of the bedrock is of very little importance in connection with the history of the lakes of the Great Lakes system."

SEDIMENTARY ROCKS ARE PROBABLY THE MOST STUDIED AND BEST UNDERSTOOD OF ANY EARTH MATERIALS. THE FACT THAT THEY ARE BEING FORMED IN LAYERS ON THE EARTH'S SURFACE TODAY ALLOWS FOR A CLEAR UNDERSTANDING OF THEIR ORIGIN INCLUDING BOTH THE PHYSICAL AND BIOLOGICAL PROCESSES WHICH PRODUCE THEM.

THE SEDIMENTARY ROCK FORMATIONS IN THE LAKE MICHIGAN REGION WERE FORMED IN THREE MAJOR GEOLOGIC ENVIRONMENTS: 1) SHALLOW TO MODERATELY DEEP SEAS IN VERY ANCIENT TIMES THAT REPEATEDLY INVADED THE CENTRAL LOWLANDS OF THE CONTINENT, 2) ON LAND DURING GLACIAL AGES WHEN MANY TYPES OF DEPOSITS WERE LAID DOWN BY MELTING GLACIERS AND MELTWATERS FLOWING FROM THESE GLACIERS, AND 3) DURING LATE GLACIAL AND POST-GLACIAL TIMES WHEN DEPOSITS ACCUMULATED IN A SUCCESSION OF LARGE, FRESH WATER LAKE STAGES AND WERE REWORKED BY THE WAVES AND WINDS. IT IS THE LATTER TWO ENVIRONMENTS THAT SERVE AS OUR FOCUS.

Era	Period and System	Epoch and Series	Age in Millions of Years
Cenozoic	Quaternary	Holocene Pleistocene	2-3
	Tertiary	Pliocene Miocene Oligocene Eocene Paleocene	65
Mesozoic	Cretaceous Jurassic Triassic		136 190-195
Paleozoic	Permian		280
	Pennsylvanian	Monongahelian Conemaughian Alleghenian Pottsvillian	
	Mississippian	Chesterian Valmeyeran Kinderhookian	395
	Devonian	Senecan and Chautauquan Erian Ulsterian Helderbergian	
	Silurian	Cayugan Niagaran Alexandrian	430-440
	Ordovician	Cincinnatian Champlainian Canadian	500
	Cambrian	St. Croixan Albertan Taconian	600
Precambrian			1,500

TABLE 1. THE GEOLOGIC TIME SCALE: ERA, PERIOD, SYSTEM, EPOCH AND SERIES NAMES USED IN THE LAKE MICHIGAN REGION.

TABLE ONE IS A GEOLOGIC TIME SCALE. NOTE THAT THE QUATERNARY PERIOD COMPRISES ONLY THE LATEST SEVERAL MILLION YEARS OF A VERY LONG EARTH HISTORY. YET IT IS THE EVENTS OF THIS PERIOD, THE TIME OF THE "ICE AGES" THAT HAVE PRODUCED THE MODERN LANDSCAPE. IN THE LAKE MICHIGAN REGION THE LANDSCAPE AND WATERSCAPE ARE THE RESULTS OF PROCESSES WHICH OCCURRED DURING THE MOST RECENT OF THESE ICE AGES, THE WISCONSINAN STAGE, AND DURING THE ENSUING PERIOD OF DEGLACIATION, THE HOLOCENE STAGE. TABLE TWO REVEALS THE TIME CALENDAR AND DEPOSITS ACCUMULATED DURING THESE STAGES OF LAKE MICHIGAN AREA EARTH HISTORY.

TABLE 2.

QUATERNARY GEOLOGIC TIME AND TIME-STRATIGRAPHIC UNITS IN THE LAKE MICHIGAN REGION (ADAPTED AFTER FRYE AND WILLMAN, 1970).

System	Series	Stage	Substage	Age in radiocarbon years
QUATERNARY	PLEISTOCENE	Holocene	LAKE MICHIGAN/CHICAGO	7,000
		Wisconsinan Glacial	**Valderan**	11,000
			Two Creekian	12,500
			Woodfordian	22,000
			Farmdalian*	28,000
			Altonian (?)	75,000
		Sangamon* Interglacial		
		Illinoian (?) Glacial		
		Yarmouthian* Interglacial		
		Kansan* Glacial		
		Altonian Interglacial		
		Nebraskan* Glacial		

*No deposits recorded in the Lake Michigan region.

WHAT ARE GLACIERS? HOW DO THEY FORM AND WHY HAVE THEY DISAPPEARED FROM THE AREAS SURROUNDING LAKE MICHIGAN? WHAT HAVE BEEN THE EFFECTS OF THESE GLACIERS? IS THE ICE AGE OVER OR WILL GLACIERS RETURN ONCE AGAIN TO THE LAKE MICHIGAN REGION? LET US CONSIDER SOME OF THESE BASIC QUESTIONS BEFORE REVIEWING THE ICE AGE HISTORY OF THIS REGION.

GLACIERS ARE LARGE MASSES OF ICE FORMED TOTALLY OR PARTIALLY ON LAND BY THE COMPACTION AND RECRYSTALLIZATION OF SNOW OVER MANY YEARS. THEY MOVE SLOWLY BY CREEPING DOWNSLOPE OR OUTWARD IN ALL DIRECTIONS DUE TO THE STRESS OF THEIR OWN WEIGHT (2). GLACIOLOGY IS THE STUDY OF GLACIERS, AND IT TREATS ALL ASPECTS OF SNOW AND ICE. MUCH IS KNOWN TODAY ABOUT GLACIERS, THEIR ORIGIN, GROWTH AND MELTING, BECAUSE TEN PERCENT OF THE LAND SURFACE OF THE EARTH (CONTINENTAL SURFACE AREA) IS COVERED BY GLACIERS. MOST OF TODAY'S GLACIAL ICE IS LOCATED IN TWO LARGE CONTINENTAL OR ICE CAP GLACIERS COVERING MOST OF THE ISLAND OF GREENLAND AND THE CONTINENT OF ANTARCTICA. ICE THICKNESSES OF THESE ICE CAP GLACIERS RANGE FROM TWO TO THREE MILES (FIGURE 1).

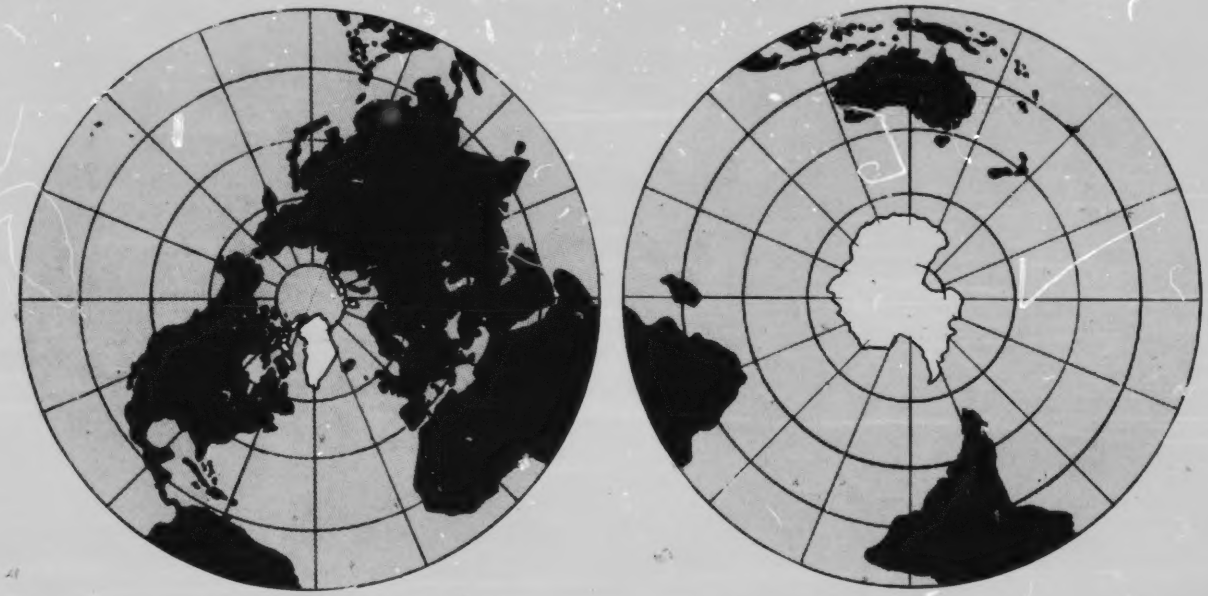

FIGURE 1. THE MAJOR GLACIER ICE FIELDS--ANTARTICA AND GREENLAND.

DURING THE QUATERNARY PERIOD IN THE PLEISTOCENE OR "ICE AGES" EPOCH, HOWEVER, AS MUCH AS 30 PERCENT OF THE SURFACE OF THE CONTINENTS WAS COVERED BY HUGE CONTINENTAL GLACIERS OR ICE CAPS. THEN, AS NOW, GLACIERS WERE PROMINENT FEATURES OF THE HIGH MOUNTAINOUS AREAS, BUT ALSO LARGE AREAS OF NON-MOUNTAINOUS TERRAIN OF NORTH AMERICA WERE COVERED BY A LARGE ICE CAP WHICH ORIGINATED FROM GLACIERS IN THE CANADIAN ROCKIES OF BRITISH COLUMBIA AND THE LOW HILLS TO EITHER SIDE OF HUDSON'S BAY. THESE GLACIERS GREW AND MERGED AND EXTENDED SOUTH AS FAR AS THE MODERN OHIO AND MISSOURI RIVERS; THEY COVERED AN AREA OF APPROXIMATELY 4 MILLION SQUARE MILES (FIGURE 2). SIMILARLY, NORTHERN EUROPE AND ASIA WERE COVERED BY NEARLY 4 MILLION SQUARE MILES OF ICE.

THESE HUGE ICE CAPS WERE THE NORTHERN HEMISPHERE PHENOMENA BECAUSE THE OCEANS, WHICH HAD A MODERATING EFFECT, RETARDED THE SPREAD OF THESE LARGE ICE SHEETS FAR OUT TO SEA. THE SOUTHERN HEMISPHERE, CONTAINING MUCH LESS LAND AREA (AND CONVERSELY A MUCH GREATER OCEAN AREA) EXPERIENCED GLACIATION LIMITED TO ANTARTICA AND THE HIGH MOUNTAINOUS REGIONS.

THE FORMATION OF GLACIERS IS STILL PARTIALLY SHROUDED BY MYSTERY. THERE IS A VERY GOOD UNDERSTANDING OF THE MECHANICS OF SNOW ACCUMULATION, CONVERSION TO ICE, AND FLOWAGE OF THAT ICE. HOWEVER, THE CAUSES OF THE WORLD-WIDE LOWERING OF TEMPERATURES (ALMOST SIX TO EIGHT DEGREES CENTIGRADE ON THE AVERAGE OVER THE YEAR), WHICH RESULTS IN ABUNDANT PRECIPITATION IN THE FORM OF SNOW, IS NOT YET CLEARLY UNDERSTOOD.

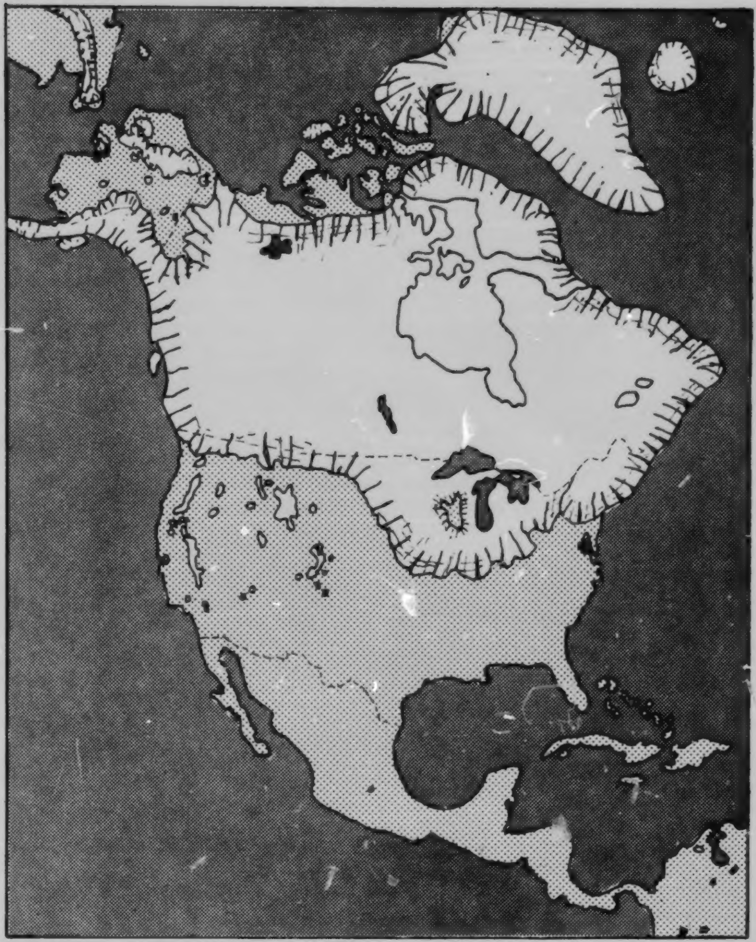

FIGURE 2. THE LAURENTIDE ICE SHEET IN NORTH AMERICA DURING THE PLEISTOCENE EPOCH.

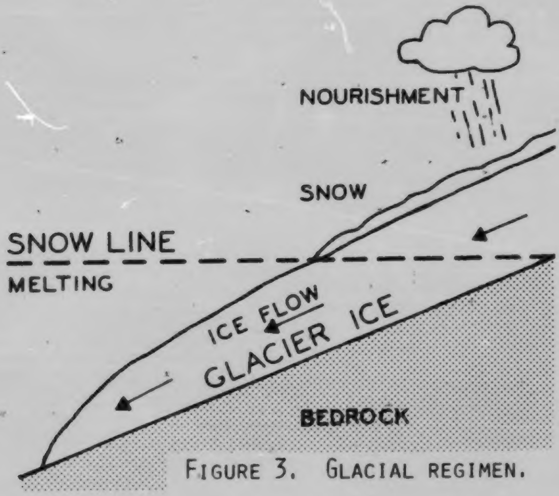

FIGURE 3. GLACIAL REGIMEN.

GLACIAL ICE IS NOT STATIC; IT IS GENERALLY CONSTANTLY IN MOTION. GLACIERS MAY ADVANCE (WHEN SNOWFALL EXCEEDS SNOWMELT OVER A SEASON); RETREAT (WHEN SNOWMELT EXCEEDS SNOWFALL OVER A SEASON); OR REMAIN IN EQUILIBRIUM (WHEN THE TWO PROCESSES ARE IN BALANCE (FIGURE 3). THE RATES OF MOVEMENT MAY BE IMPERCEPTIBLE (INCHES OR FEET PER DAY) BUT INEXORABLE AND OVER THE MANY THOUSANDS OF YEARS OF THE ICE AGES, GLACIERS HAVE TRAVELLED GREAT DISTANCES AND IN DOING SO HAVE ALTERED THE LANDSCAPE COMPLETELY. THEY HAVE LITERALLY GROUND VERY SLOWLY OVER THE SURFACE; CHANGING SOFT ROCKS, SUCH AS SHALE, LIMESTONE AND dolomite into rock flour, and harder rocks, such as granite and quartzite, into small fragments. Indeed, glaciers are the greatest erosive agents in their intensity and ability to change the landscape.

The ground up rock fragments and flour are called till. It is deposited beneath the glacier especially near its outer margins and at the outer margin of the glacier. In an advancing glacier these deposits are overrun, reworked and redeposited. In a retreating glacier, they accumulate in the marginal areas of the ice. However, in a glacier in dynamic equilibrium, these deposits build in thickness at the "fixed" margin or snout of the glacier producing a hilly deposit of till called an end or terminal moraine. It is these moraines and the meltwater deposits flowing from them, the outwash deposits, that dominate the landscape of the Central Lowlands and form a margin of low hills generally bordering modern Lake Michigan (Figure 4).

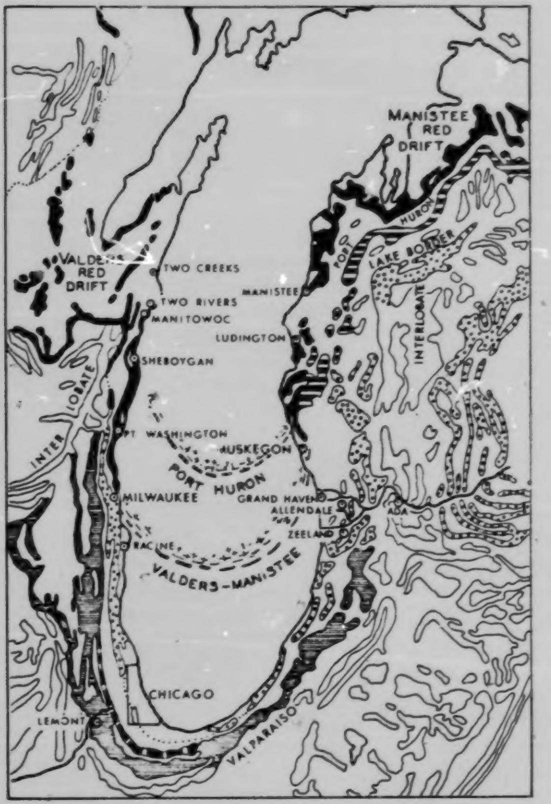
Manistee
Red
Drift
Valders
Red
Drift
Two Creeks
Two Rivers
Manitowoc
Manistee
Ludington
Sheboygan
Port Huron
Lake Border
Interlobate
Interlobate
?
Pt Washington
Muskegon
Port Huron
Milwaukee
Grand Haven
Allendale
Ada
Zeeland
Racine
Valders-Manistee
Chicago
Lemont
Valparaiso

Figure 4. Glacial deposits of the Lake Michigan region.

An intriguing factor of Pleistocene or Ice Ages glaciation is its multiplicity. There was not just one major glacial advance and retreat but four which covered the Central Lowlands. Between each ice age the climate warmed, and indeed, was possibly slightly milder than today's weather conditions. These interglacial ages were of much greater duration than the glacial ages. Only in three of these great ice ages did glaciers cover the Lake Michigan region and it is only the deposits of the most recent ice age that are discernible or preserved in this region.

Pre-Wisconsinan Ages

At the beginning of the Pleistocene Epoch (Figure 1), the Lake Michigan region was part of a stream eroded upland plain underlain by a thick soil developed on Paleozoic rocks. A northward-flowing major river had carved a broad and deep valley in the softer shales and carbonate rocks on the east flank of the Kankakee Arch and Wisconsin highlands, in the area now occupied by Lake Michigan (Figure 5). The effects of subsequent, repeat-

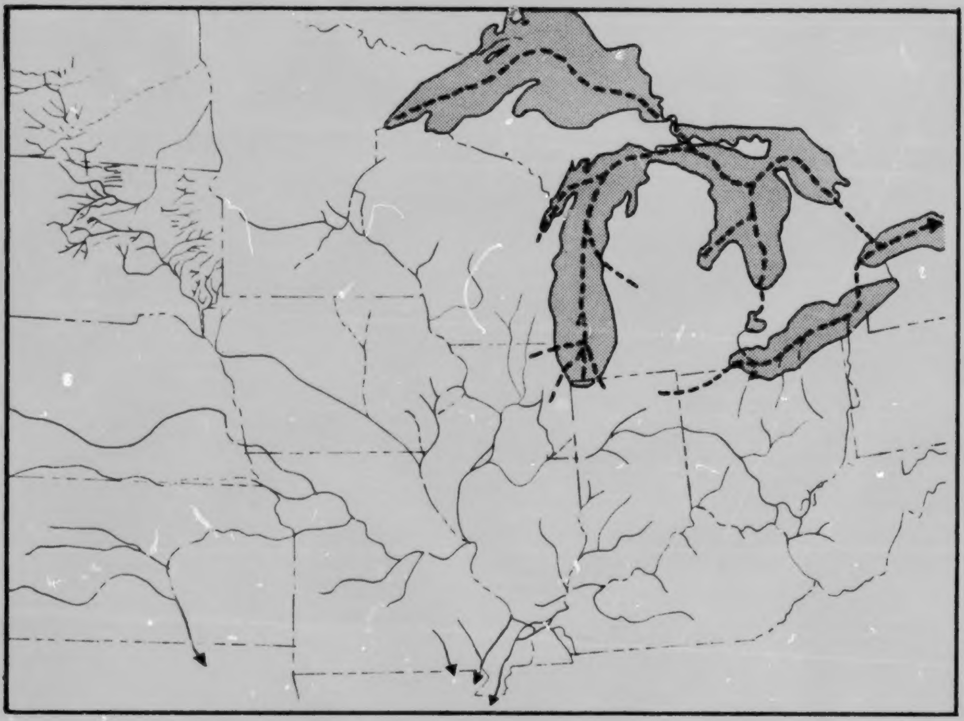

FIGURE 5. PREGLACIAL DRAINAGE IN THE GREAT LAKES REGION.

ED GLACIAL ADVANCES WERE TO DEEPEN AND WIDEN THIS MAJOR VALLEY AND SUBDUE AND "SOFTEN" THE BEDROCK TOPOGRAPHY IN THE REGION, REMOVING ALL TRACES OF SOIL FORMATION.

IT IS UNLIKELY THAT THE EARLIEST PLEISTOCENE GLACIATION, THE NEBRASKAN ICE ADVANCE, EVER COVERED THE LAKE MICHIGAN REGION. PRESENT EVIDENCE SUGGESTS THIS GLACIER, HAVING BEEN A WESTERN ADVANCE, WHICH IN ITS PROGRESS SOUTHWARD AND EASTWARD, NEVER REACHED CLOSER TO THE LAKE MICHIGAN REGION THAN WEST-CENTRAL ILLINOIS.

THE MOST EXTENSIVE NORTH AMERICAN GLACIATION WAS IN THE KANSAN AGE WHEN GLACIERS BLANKETED THE AREA AS FAR SOUTH AS KENTUCKY. THE LAKE MICHIGAN REGION WAS COVERED BY GLACIERS. SUBSEQUENT GLACIERS DURING THE ILLINOIAN AND WISCONSINAN ICE AGES MAY HAVE DEVELOPED ONLY AFTER THIS EARLIER GLACIATION HAD GREATLY MODIFIED THE MICHIGAN RIVER VALLEY, WIDENING AND DEEPENING IT. THUS, A TOPOGRAPHY WAS CREATED SUCH THAT WHEN SUBSEQUENT GLACIERS DEVELOPED, THEY SPREAD MORE READILY THROUGH BROADENED VALLEYS THAN OVER INTERVENING UPLANDS LEAVING THE IRREGULAR, LAKE-LIKE GLACIAL TILL DEPOSITS OF THE MODERN LANDSCAPE.

WISCONSINAN AGE

WISCONSINAN GEOLOGIC HISTORY IS DOMINATED BY TWO MAJOR EVENTS IN THE LAKE MICHIGAN REGION: (1) A "STUTTERING" ADVANCE AND RETREAT OF GLACIERS IN WHAT IS DEFINED AS THE

20

Lake Michigan Lobe, and (2) the evolution of Lake Michigan from a body of water confined between the glacier front and the surrounding uplands called Lake Chicago, to the modern Great Lake (Table 2).

Altonian Time: The Altonian glacier, the earliest Wisconsinan glacier, advanced southward into the Lake Michigan Basin, overflowed the basin, and spread southwest through northeastern Illinois and northwestern Indiana. As the ice front retreated, the glacier deposited till materials called the Winnebago deposits.

The Altonian ice probably arrived in the southern Lake Michigan region 60,000 radiocarbon years ago. Several advances and retreats of the glacier occurred before the end of Altonian times--28,000 radiocarbon years ago.

Farmdalian Time: The glaciers retreated during Farmdalian time, but remnants of a cold-climate vegetation to the west of Chicago, in the Robein Silt, suggest the ice may not have melted entirely from the Lake Michigan Basin. The Farmdalian ice-withdrawal interval extended from 28,000 to 22,000 radiocarbon years ago. Whether or not ice-contact lakes existed in the Lake Michigan Basin during this interval, can only be a matter of speculation.

Woodfordian Time: The two major events of Woodfordian time are glacial advance and retreat depositing glacial drift deposits and the evolution of ancestral Lake Michigan. The chronologies of these two events overlap and the following discussion treats first, the glacial history and second, the lake history.

The Woodfordian marks the maximum Wisconsinan glaciation. The Lake Michigan Lobe glacier extended nearly to the Mississippi River in Illinois and to central Indiana where it merged with ice from the eastern lobes. The spasmodic or pulsating advances and retreats of the glacier lasted from 22,000 to 12,500 radiocarbon years ago. At the maximum of ice advance the southern edge of the Lake Michigan region was covered by perhaps 3,000 to 5,000 feet of glacial ice.

During the first several thousands of years the Woodfordian glaciers were advancing; the rate of nourishment and flow of the ice exceeded the rate of melting. But after the glacier reached its maximum extent, a general warming of the climate caused melting to exceed snow nourishment and the forward flow of the glacier, and the ice front retreated. The retreat of the glacier from its maximum extent was interrupted by intervals of colder climate that caused readvances of the ice front. It is these readvances in the Lake Michigan region that are recorded as distinct till drifts. During each stand of the ice front, before renewed retreat and after readvancing, the melting and ice advance were about equal and an end moraine was formed by the continuing deposition of till at the ice front.

About one half of Woodfordian time involves the advance of the Michigan Lobe glacier to its maximum extent. The second half of Woodfordian time comprises the spasmodic, pulsating retreat of the ice front to the general vicinity of the southern edge of present day Lake Michigan.

Thus, it is during the later Woodfordian that three successive readvances of the Lake Michigan Lobe glacier, the Valparaiso, Tinley and Lake Border, moved out of the northern basin and covered the southern margin of the basin. The exact age of the Valparaiso glacial advance is not known (no radiocarbon dates are available) but probably occurred between 15,000 and 17,000 years ago. At Valparaiso glacial maximum and during the ensuing ice recession, great volumes of meltwater sluiced sand and gravel into the broad valley beyond the moraines.

After the building of the Valparaiso Moraine, the ice front retreated an unknown distance northward before readvancing to the position of the Tinley Moraine (Figure 4). The Tinley glacier crept over the northern margin of the Valparaiso Moraine and deposited till in standing water. When the ice front retreated northward from the Tinley Moraine, the land surface northward behind the moraine, the Lake Michigan Basin, was below the level established by the Tinley Drainage, essentially a depression. The Tinley drainage at its lowest point emptied through the Timley and Valparaiso Morainic systems via the Des Plaines River and the Chicago Sag Channel near Lemont, Illinois (Figure 4). The meltwater from the receding Michigan Lobe glacier soon flooded the area to the level of the outlet or spillway at Lemont. This created the initial stage of Lake Chicago, an ice-contact lake and the forerunner of the modern lake (Figure 6).

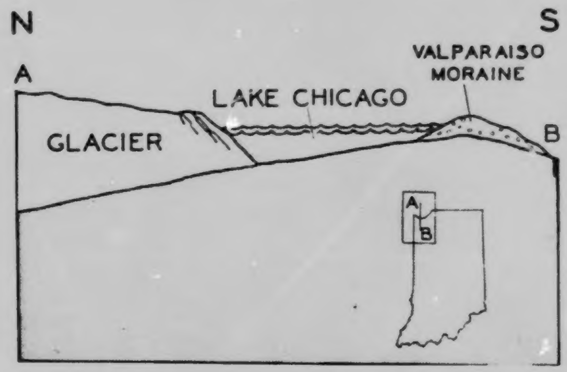

Figure 6. Ancestral Lake Michigan (Lake Chicago), an ice contact lake.

During this initial lake phase, the Glenwood Stage of Lake Chicago, the Lake Michigan Lobe glacier readvanced for the final time beyond the southern margin of present day Lake Michigan. The Lake Border glacier deposited till in standing water, producing a narrow upland called the Lake Border Moraine (Figure 4).

The Lake Border glacier receded northward in the basin and about 13,200 radiocarbon years ago, a great influx of water from the Huron and Erie Basins flowed through the Grand River Valley across central Michigan and into Lake Chicago. The effect was to increase the erosional activity of the outlet streams at Lemont. Thus, the lowering of lake level by 20 feet shifted the shoreline northward and began the Calumet Stage of Lake Chicago (Figure 7 and Table 3). At each of these lake level stages, an assemblage of shoreline features was deposited. Beaches, bars, shoals, spits and, shoreward, cliffs were cut and sand dunes accumulated.

Age	Subage	Years Before Present	Lake Stage		Elevation
HOLOCENE		2,000 -	L. Michigan		580'
		3,000 - 2,000	Algoma		590'
		4,000 - 3,000	Nipissing		605'
WISCONSINAN	Valderan	9,000	Chippewa		230'
		10,300 - 9,400	Algonquin		605'
		11,000 - 10,300	Tolleston	L. Chicago	605'
	Two Creekian	11,400 - 11,000	Calumet II		620'
		11,800 - 11,400	Bowmanville		585'(?)
		12,800 - 12,000	Calumet I		620'
	Woodfordian	14,000 - 13,200	Glenwood		640'

Table 3. Summary of southern Lake Michigan Basin lake stages and the elevation and ages of glacial lakes therein.

The retreat of the Lake Michigan Lobe glacier continued through the close of Woodfordian time. The end of the Woodfordian 12,500 radiocarbon years ago is marked by the Michigan Lobe glacier retreating north of the Straits of Mackinac and the now large lake, draining eastward and abandoning the Lemont outlet for a time. This occurred some 11,800 radiocarbon years ago (Table 3).

Two Creekian Time: A low water stage of Lake Chicago is indicated by an extensively radiocarbon dated forest bed at Two Creeks, Wisconsin. The Two Creeks Forest Bed is interpreted as indicating a low water stage of the lake which was named the Bowmanville (Table 3). At Two Creeks, Wisconsin, the forest bed is overlain by Valderan till indicating a readvance of the glacier into the Lake Michigan Basin.

Valderan Time: When the Michigan Lobe glacier readvanced, it blocked eastward drainage via the Straits of Mackinac. Lake Chicago soon rose again to the level of the Lemont Outlet and the Calumet Shoreline was reoccupied (Table 3). Thus Valderan time in the Lake Michigan region is marked initially by a rise in lake level and establishment of Calumet II Stage from 11,400 to 11,000 years ago. Shoreline deposition and dune building continued.

Continued erosion of the Lemont Outlet channel degraded the outlet channel to 605 feet (Figure 7 and Table 3). At this point, the channel was entrenched in Paleozoic bedrock which served as a barrier to any substantial further channel lowering. With the outlet at 605 feet, the shoreline in the Lake Michigan region receded northward and shoreline deposits accumulated, forming the Tolleston dune and beach complex (Table 3 and Figure 7). This shoreline was reoccupied twice afterwards and shoreline deposits of each lake occupance are discernible. The Tolleston Stage lasted from 11,000 to 10,300 years ago (Table 3). The Valders glacier was at its maximum of advance depositing a distinctive red till on land and in the lake many miles to the north (Figure 4). Beyond the ice front, beds of red clay were also deposited in the lake.

When the Valders glacier melted and retreated northward, again freeing the eastern outlet through the Mackinac Straits, the lakes in the Michigan and Huron Basins were merged and Lake Algonquin came into existence (Figure 8 and Table 3). Lake Algonquin continued to drain through the Lemont Outlet and persisted from 10,300 to 9,400 years ago. The 605 foot shoreline was reoccupied and the Tolleston and Algonquin beach and dune complexes merged.

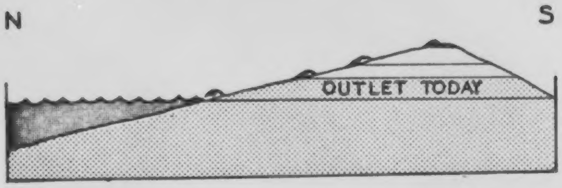

Figure 7a. Elevations of Lake Chicago shorelines.

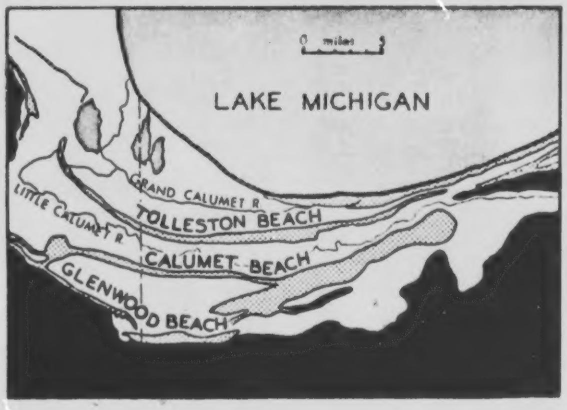

Figure 7b. Geography of Lake Chicago shorelines at the southern margin of the lake.

The further retreat of the ice northward opened the North Bay Outlet from the Lake Huron Basin, through Ontario, to the St. Lawrence Valley. The land in that area had not risen to its pre-glacial elevation above sea level (isostatic adjustment) following the removal of the weight of the ice which had depressed the land. The St. Lawrence Valley was below sea level because of this depression and the Gulf of St. Lawrence extended inland to the North Bay Outlet. This resulted in a draining of Lake Algonquin and the shrinking to much smaller lakes in each lake basin. The culmination of this shrinkage produced Lake Chippewa in the Michigan Basin at an elevation of 230 feet above sea level about 9,000 years ago (Figure 9 and Table 3). Lake Chippewa covered only the deepest parts of the Lake Michigan Basin and the shoreline stood many miles lakeward from today's lake margins.

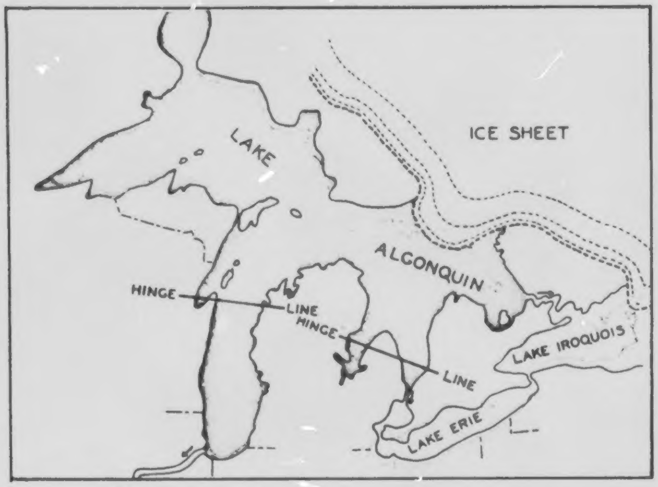

Figure 8. The Algonquin stage of Lake Michigan evolution.

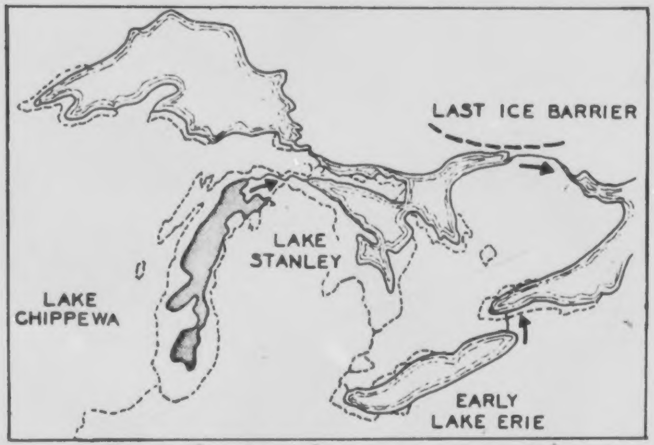

Figure 9. Lake Chippewa during final glacial retreat.

Holocene Time: The Holocene Age began with the final retreat of the glaciers about 7,000 years ago. At this time most of the glacial ice had melted from the continents and sea level and risen to nearly the present level.

Uplift of the land due to isostatic adjustment, in the North Bay Outlet area in Ontario, closed that outlet and lake levels rose in the Great Lakes Basins (Figure 10). Lake level reached 605 feet again and the Chicago (Lemont) Outlet was used once more along with a southeastern outlet in the Lake Huron Basin, the St. Clair River outlet to Lake Erie. This was the Nipissing Great Lakes which persisted from 4,000 to 3,000 years ago and accumulated shoreline deposits in the Lake Michigan region (Figure 8, 11, and Table 3).

The St. Clair River outlet was cut in till which eroded rapidly while the bedrock outlet at Lemont was a barrier to channel lowering and was eventually abandoned for the eastern outlet. Lake level dropped to 590 feet creating Lake Algoma, which persisted from 3,000 to 2,000 years ago (Table 3).

Lake Algoma ended when continued downcutting of the St. Clair River channel to 580 feet occurred. Lake Michigan at that general level, is considered to have evolved about 2,000 years ago (Table 3). Even today the lake level continues to fluctuate as is strikingly indicated by the shoreline erosion which occurred during the three higher lake level phases of this century in the Lake Michigan region.

The lake history described above is derived from a compilation by Willman and is only one of a variety of possible interpretations of the sequence and timing of lake stages (5). Although the general lake history is agreed upon, much disagreement exists concerning the very specific sequence of events.

Thus, the entire Great Lakes region is comprised of a wide variety of landforms of glacial origin. A very extensive landscape unit, the Central Lowlands Physiographic Province is a broad, relatively low and irregularly shaped area. This province roughly outlines the glaciated area from the Appalachians on the east to the Great Plains on the west and from the Superior Uplands on the north to the Interior Low Plateaus and the Ozark Plateaus on the south (Figure 12). Locally in this province, relief seldom exceeds several hundred feet. The section of the Central Lowlands Province which embraces the broader Lake Michigan area is the Great Lakes Section.

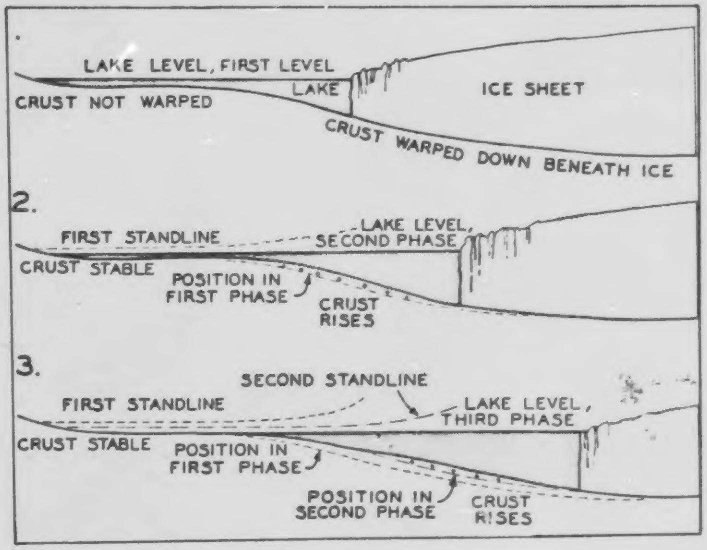
LAKE LEVEL, FIRST LEVEL
LAKE
ICE SHEET
CRUST NOT WARPED
CRUST WARPED DOWN BENEATH ICE
2.
FIRST STANDLINE
LAKE LEVEL, SECOND PHASE
CRUST STABLE
POSITION IN FIRST PHASE
CRUST RISES
3.
SECOND STANDLINE
FIRST STANDLINE
LAKE LEVEL, THIRD PHASE
CRUST STABLE
POSITION IN FIRST PHASE
POSITION IN SECOND PHASE
CRUST RISES

Figure 10. The isostatic uplift after glacial retreat.

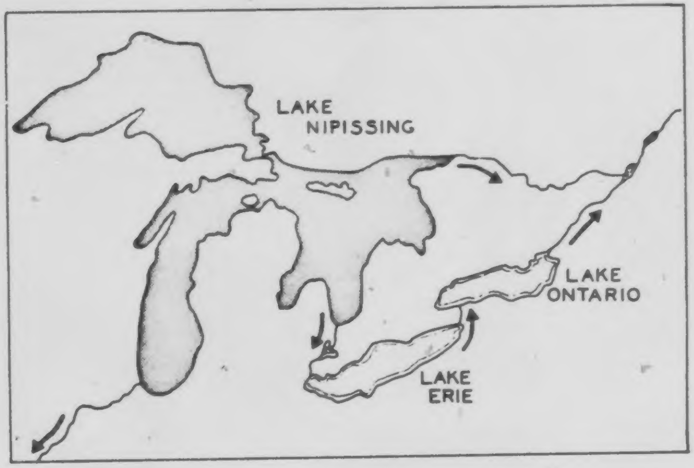
LAKE NIPISSING
LAKE ONTARIO
LAKE ERIE

Figure 11. Lake Nipissing, a post-glacial Great Lake.

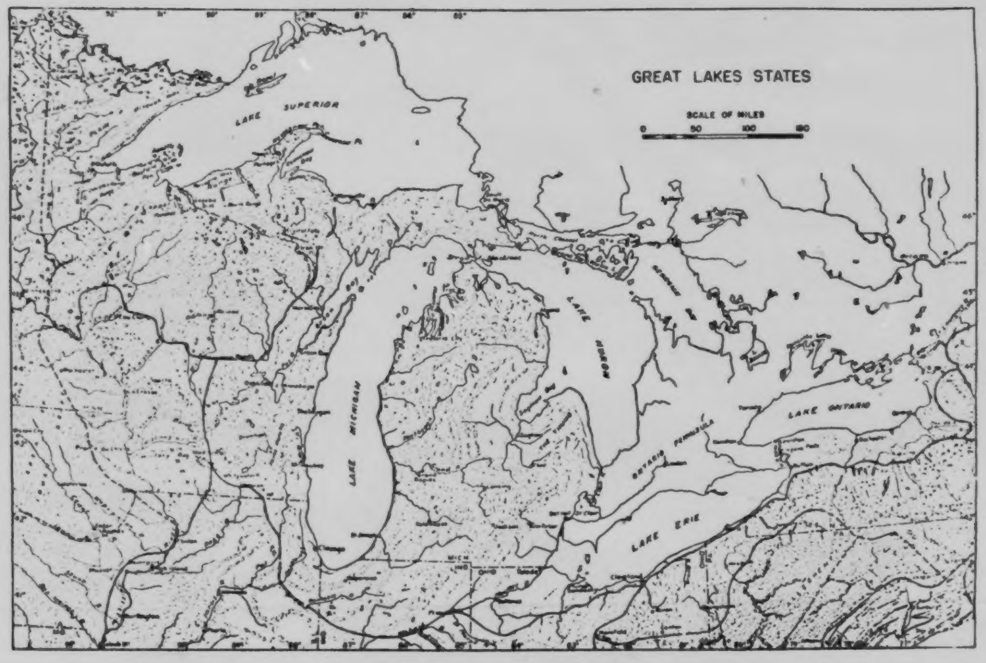

Figure 12. Central Lowlands Physiographic Province: N. M. Fenneman, Physiography of Eastern United States, 1938, McGraw Hill, N.Y., Plate IV.

Unconsolidated earth materials, comprised of sediments ranging from loosely compacted sands to highly compressed clays and silts, mantle the bedrock surface of the Lake Michigan region in thicknesses reaching upwards of 200 feet. These deposits of both direct and indirect glacial origin and sometimes loosely referred to as "drift" or "glacial drift", mask an erosional surface carved in the underlying bedrock by streams over many millions of years prior to the ice ages. This buried bedrock topography is markedly different from the present surface reflecting a maturely developed landscape produced over a very long time period.

Landscape elements comprising the present surface topography are largely depositional or constructional in nature as a result of the very recent glaciation. They consist of hills of pebbly clay called moraines, extensive sandy plains and smaller deltas of glacial meltwater origin, flood plains and lake plains, and sandy beaches and dunes. Erosional features present in the landscape include extensive cliffed shoreline; wind eroded hollows in the sand dune complexes termed blowouts; and many valleys eroded by streams in the glacial drift deposits following the melting and retreat of the last great glacier. The surface topography both in terms of actual years and stage in a possible erosional cycle is youthful.

It is the association of beaches, cliffs, dunes and blowouts that typifies the popular character of the Lake Michigan region shoreline. These are the picturesque features at the water's edge. Waves and currents, generated mainly by wind blowing over long stretches of Lake Michigan, act together to create and destroy beaches and portions of these coastal dunes and cliffs. The pattern of beach and dune, so noticeable along the southern and eastern edges of Lake Michigan, is repeated at least three times in a stepwise fashion inland along the ancient margins of ancestral Lake Michigan or Lake Chicago with the older shoreline sand dunes mostly stabilized by vegetative growth. The following discussion provides a simplified view of the processes involved in producing shoreline features.

Waves in the Breaker Zone

Wind-generated waves involve some movement of surface water due to the manner in which they form. The friction of the wind on the water surface sweeps material before it, but in general, the amount of water moved is so small that it can be disregarded except in the breaker zone where the water becomes shallower.

As the wave crests and troughs approach the beach, the orbital motion of the water particles within the wave form is affected by drag along the lake's bottom. The wave's forward rate of motion remains unchanged, but the wave length is shortened and the wave height increases and the wave crests become sharper. The wave steepness (height divided by length) continues to increase until the wave length is only about seven times as great as wave height, at which time the crest peaks and finally breaks and the water in the wave crest tumbles forward up the beach. (Up to this point, only a small portion of the water was actively moving with the wave.)

Seiches

Seiches (the temporary oscillation or piling up of water in a lake, bay, or harbor in response to winds, air pressure gradients, or seismic activity) can in rare cases cause increased, short-duration erosion of the shoreline. The most typical type of seich on Lake Michigan is the storm tide or surge. During a severe storm, a substantial rise in lake level can occur, because a moving low-pressure area surrounded by high-pressure zones produces a doming of the water under the low-pressure area. As the low-pressure area (storm center) moves landward, so does the dome of water. This doming, added to the large wind-generated waves, increases the power of the storm with resulting higher water level and more erosive waves.

Offshore Bars and Ripples

Sediment disturbance and movement resulting from wave action occur in the breaker or surf zone. It is here that waves actually come in contact with lake bottom sediments and act directly upon them. The commonest form of sediment movement along the nearshore lake bottom is the generation of sand ripples and their larger forms, the offshore bars. When the orbital motion of a wave is brought to bear against bottom sediments, the materials are picked up and moved in much the same way as a spinning automobile tire throws loose stones on a gravel road (Figure 13). Wave-generated ripples result from the combined effects of the oscillations of many waves. Sand ripples can result from other causes, however, as shown in the sections on beaches and sand dunes.

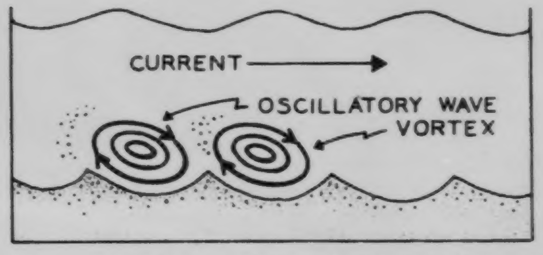

Figure 13. Formation of sediment ripples by wave action.

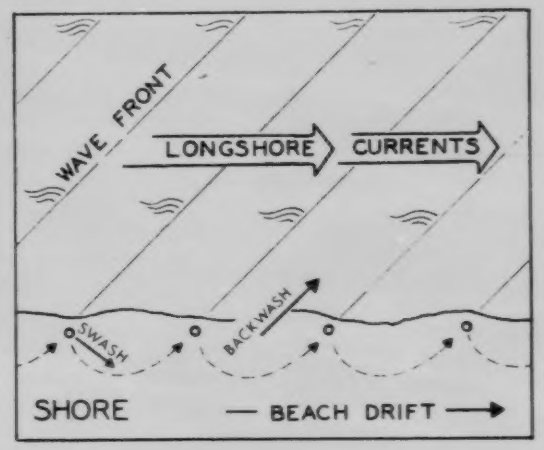

Figure 14. Longshore currents: generated in response to waves striking the shore obliquely. ▶

Offshore bars are generated in much the same way as sand ripples but on a larger scale. The main difference, other than that of scale, is that bars are usually the product of lake currents as well as waves. There are two to three semiparallel bar systems off the southern and eastern shores of Lake Michigan. The outermost bar has a core of coarse rock rubble, and the inner one or two are composed primarily of sand. Some oceanographers refer to bars of this type as shoaling bars as they result from the shoaling process (the action of waves contacting bottom materials in shallow water as discussed above).

Waves, because of the enormous amount of energy transmitted by them, can cause considerable erosion of a shoreline. The continuous pounding of breakers can disintegrate even the strongest concrete structures over a period of time. At the other end of the spectrum, gently rolling waves carry bottom sediments to the shore causing accretion or nourishment. The balance between erosion and deposition, as caused by waves, is expressed by nature in the form of an everchanging beach.

CURRENTS

THERE ARE SEVERAL TYPES OF CURRENTS THAT OCCUR IN LAKE MICHIGAN, BUT ONLY THOSE WHICH AFFECT THE VERY NEARSHORE ENVIRONMENT ARE DISCUSSED HERE; THE LONGSHORE CURRENT AND THE RIP CURRENT. WAVES THAT APPROACH THE SHORE AT AN OBLIQUE ANGLE GENERATE A CURRENT THAT TRAVELS PARTLY IN THE DIRECTION FROM WHICH THE WAVES APPROACH AND PARTLY PARALLEL TO THE SHORE (FIGURE 14). THE ACTUAL MECHANICS OF LONGSHORE CURRENT GENERATION ARE QUITE COMPLEX BUT THE NET EFFECT OF LONGSHORE CURRENTS IS LITTORAL DRIFT OR THE MASS TRANSPORT OF SEDIMENTS IN THE DIRECTION OF LONGSHORE CURRENT MOVEMENT. SAND TRANSPORT IS PRIMARILY RESTRICTED TO THE AREA BETWEEN THE OUTER BAR AND THE SHORE. HIGH-INTENSITY WAVES STRIKING THE SHORE OBLIQUELY TEND TO GENERATE LONGSHORE CURRENTS OF SUFFICIENT STRENGTH TO MOVE BOTTOM SEDIMENTS FROM ONE POINT ALONG THE BEACH TO ANOTHER. OBSTACLES WITHIN THE WATER, SUCH AS MANMADE FEATURES, SAND BARS, OR SPITS, CAUSE THE LONGSHORE CURRENT TO SLOW, THUS REDUCING ITS ABILITY TO TRANSPORT THE HEAVIER BOTTOM MATERIALS SUCH AS COARSE SAND AND FINE GRAVEL (FIGURE 15). AS A CONSEQUENCE, THE COARSER SIZE GRADE MATERIALS ACCUMULATE ON THE UPCURRENT SIDE OF SUCH A PROJECTION. IN LIKE MANNER, THE PRESENCE OF OFFSHORE BARS ALSO IMPEDES LONGSHORE-CURRENT FLOW AND CAUSES DEPOSITION OF SAND ALONG THE LENGTH OF THESE BARS. THE END RESULT IS FURTHER GROWTH OF THE BARS OR ACCUMULATION OF SEDIMENTS ON THE UPCURRENT SIDES OF LAKEWARD PROJECTIONS AND, DUE TO A LACK OF SAND NOURISHMENT, EROSION ON THE DOWNCURRENT SIDE OF SUCH FEATURES. THE PRIMARY RESULT OF LONGSHORE CURRENTS IS THE DISTRIBUTION OF SEDIMENTS ALONG THE SHORELINE.

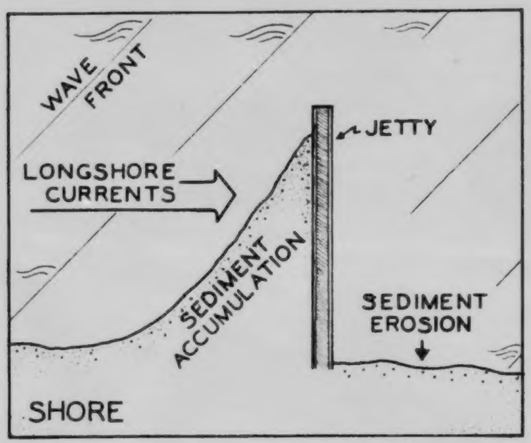

FIGURE 15. LONGSHORE CURRENT ACTION.

ALONG THE SOUTHEASTERN PART OF THE LAKE, THE PREVAILING LONGSHORE CURRENTS ACT FROM THE EAST AS INDICATED BY THE ACCUMULATION OF SEDIMENTS ON THE EASTERN SIDE OF THE MICHIGAN CITY HARBOR BREAKWATER AND THE SEVERE RECENT EROSION IMMEDIATELY WEST OF THAT STRUCTURE.

THE SMALL NET WATER MOVEMENTS ASSOCIATED WITH WIND-GENERATED WAVES ARE INSIGNIFICANT ON THE OPEN WATER. HOWEVER IN THE NEARSHORE AREA WHEN TAKEN IN COMBINATION WITH THE WATER MOVEMENT CAUSED BY THE WAVE-BREAKING ACTION, THE VOLUME OF WATER MOVING INTO THE BEACH MUST BE RETURNED TO THE LAKE IN ORDER TO MAINTAIN THE OVERALL BALANCE OF THE WATER WEIGHT. THE RETURN FLOW IS CALLED A RIP CURRENT, AND IT CONSISTS OF THREE PARTS. THE SHOREWARD WAVE-INDUCED WATER MOVEMENTS FORCE WATER TO THE BEACH. IN PART OF THE SURF ZONE, THE WATER FLOWS NEARLY PARALLEL TO THE BEACH FOR SHORT DISTANCES CREATING ANOTHER KIND OF "LONGSHORE

CURRENT". THESE LATERAL CURRENTS COMBINE TO FORM JETLIKE STREAMS THAT FLOW THROUGH THE SURF RETURNING LAKEWARD THE WATER BROUGHT IN BY THE WAVES (FIGURE 16). ON THE BEACH, RIP CURRENTS CAN BE LOCATED BY THE ABSENCE OF SURF IN THE AREA OF THE CURRENT. GENERALLY, RIP CURRENTS OCCUPY CHANNELS THAT ARE ERODED INTO THE LAKE BOTTOM. THE WATER IN THESE CHANNELS IS OFTEN DARKER DUE TO ITS GREATER DEPTH.

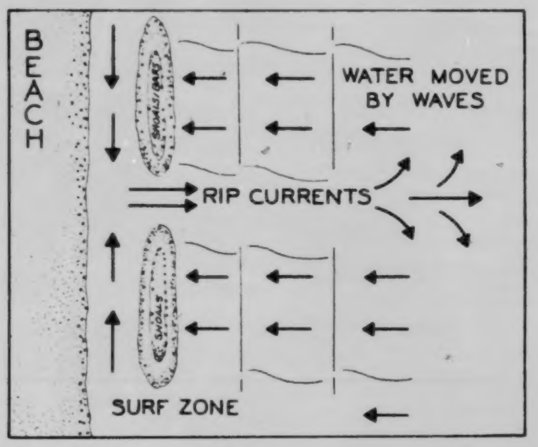

FIGURE 16. RIP CURRENT MOVEMENT IN A LAKE.

THE LONGSHORE COMPONENT OF RIP CURRENTS CARRIES SEDIMENTS PARALLEL TO THE SHORE JUST AS THE LONGSHORE CURRENTS MENTIONED ABOVE. ALTHOUGH IT IS DIFFICULT TO DIFFERENTIATE BETWEEN THE TWO CURRENTS BECAUSE OF THEIR CLOSE PROXIMITY, GENERALLY THE MAJOR LONGSHORE CURRENTS OPERATE FROM THE SURF ZONE, WHEREAS THE LATERAL RIP CURRENTS ARE RESTRICTED TO THE BREAKER ZONE. WAVE-GENERATED BAR STRUCTURES ARE FREQUENTLY BREACHED BY RIP CHANNELS AND ARE, THEREFORE, DISCONTINUOUS RIDGES. GENERALLY ONLY THE INNERMOST OF THE SEVERAL BARS FOUND ALONG THE SHORE OF LAKE MICHIGAN IS AFFECTED BY RIP CURRENTS.

BEACHES

THE PRESENT SAND BEACHES ALONG THE LAKE MICHIGAN SHORES HAVE DEVELOPED OVER THE PAST SEVERAL THOUSAND YEARS AND NOW EXIST AT AN ELEVATION OF ABOUT 580 FEET ABOVE SEA LEVEL. THE BASIC PROCESSES FORMING THESE SAND BEACHES ARE COMPLEX AND THESE LANDFORMS ARE DYNAMIC SHORELINE FEATURES. LAKE BASIN CURRENTS, ESPECIALLY THE PREVAILING LONGSHORE CURRENTS, CARRY SAND SLOUGHED OFF CLIFFS NEAR THE WATER'S EDGE AND SEDIMENTS CARRIED TO THE LAKE BY THE MANY STREAMS WHICH DRAIN TO THE LARGE WATER BODY, TO THE SOUTH ALONG BOTH THE EASTERN AND WESTERN SHORES OF THE LAKE. THERE WAVES, IN COMBINATION WITH LOCAL LONGSHORE CURRENTS, ACT ON THE ACCUMULATION OF SAND, CARRYING IT TOWARD THE SHORE WHERE IT IS DEPOSITED AS A BEACH.

BUT THE BEACH IS IN A PERPETUAL STATE OF CHANGE BECAUSE LAKE LEVELS VARY WITH TIME, THUS CHANGING THE RELATIVE POSITION OF THE WATER LINE WITH RESPECT TO THE BEACH. WIND DIRECTIONS ARE VARIABLE, CAUSING THE WAVES GENERATED BY THEM ALSO TO CHANGE DIRECTIONS. THE FORMATION AND SHIFTING OF ANY UNDERWATER FEATURES, SUCH AS A SAND BAR, CAUSES CHANGES IN WAVE AND CURRENT PATTERNS WHICH, IN TURN, CAUSE FURTHER ALTERATION OF THE BEACH. MAN-MADE STRUCTURES SUCH AS LANDFILLS, BREAKWATERS, AND VARIOUS OTHER LAKEWARD PROTRUSIONS

CAUSE CHANGES IN CURRENT AND WAVE PATTERNS THAT ALSO AFFECT THE BEACH TO VARYING DEGREES.

THE SIZE AND FORM OF THE BEACH, WHETHER IT IS NARROW OR WIDE, STEEP OR SHALLOW, DEPENDS UPON THE TYPE AND ENERGY OF THE WAVES AND CURRENTS ACTING UPON IT AND UPON THE FORM OF THE LAND ON WHICH THE BEACH EXISTS. GENTLY ROLLING BREAKERS STRIKING THE SHORE NEARLY HEAD ON CARRY SAND UP ONTO THE BEACH AND CAUSE BEACH ACCRETION. POWERFUL BREAKERS STRIKING THE SHORELINE AT SHARP ANGLES BREAK UP BEACH DEPOSITS AND CAUSE THEM TO MOVE IN THE DIRECTION IN WHICH THE WAVES TRAVEL. CONTINUOUS BOMBARDMENT OF THE SHORE BY STRONG OBLIQUELY STRIKING WAVES ULTIMATELY RESULTS IN A NARROW POORLY DEVELOPED BEACH OR IN NO BEACH AT ALL.

EACH SIZE IS ALSO CONTROLLED BY THE GEOMETRY OF THE LAND THAT THE WAVES STRIKE. IF THE SHORELINE FALLS OFF SHARPLY TO THE WATER'S EDGE, THERE IS OBVIOUSLY LITTLE ROOM FOR THE DEVELOPMENT OF A BEACH. EITHER SAND ACCRETION AT THE BASE OF THE SHORE BLUFF OR A LOWERING OF LAKE LEVEL ARE REQUIRED TO PRODUCE A BEACH OF NOTABLE EXPANSE IN SUCH A SITUATION.

THE STEPLIKE BREAK IN SLOPE SEPARATING THE SURF ZONE FROM THE BEACH IS CALLED THE BERM. PRESENCE OR ABSENCE OF THE BERM IS DETERMINED BY THE SIZE AND INTENSITY OF WAVES STRIKING THE SHORE. HIGH-ENERGY EROSIVE WAVES TEND TO CUT INTO THE BOTTOM OF THE SURF ZONE, THUS REMOVING SAND FROM THE AREA. THIS CUTTING PROCESS LEAVES A SCARP OR BERM (WAVE-CUT BERM) AS THE WAVES WITHDRAW. RELATIVELY SLOW MOVING, LOW ENERGY WAVES CAUSE SAND TO BE BROUGHT ONTO THE BEACH RATHER THAN CARRYING IT OFF. THE RESULT IS A GRADUAL SLOPE FROM THE SURF ZONE UP ONTO THE BEACH. ALTHOUGH THE BERM (WAVE-BUILT BERM) ON SUCH A BEACH MAY BE VERY LOW AND INDISTINCT, CAREFUL OBSERVATION MAY REVEAL ITS PRESENCE.

SAND IS NOT THE ONLY SIZE OF EARTH MATERIAL FOUND ON THE BEACH. IN SOME LOCATIONS THERE IS AN ABUNDANT SUPPLY OF WAVE-FLATTENED PEBBLES AND ROUNDED STONES. THE STONES ARE BROUGHT ON SHORE BY THE HIGHER ENERGY WAVES AND, IF LEFT UNDISTURBED, THEY MAY OVERLAP ONE ANOTHER LIKE SHINGLES ON A ROOF. THUS, OVERLAPPED BEACH PEBBLES ARE REFERRED TO AS SHINGLE BEACH.

CLIFFS

WHERE THE LAND SLOPES STEEPLY DOWN TO THE WATER'S EDGE, WAVES CAN ERODE THE SHORES IN THREE WAYS: (1) BY IMPACT AND HYDRAULIC PRESSURE; (2) BY ABRASION OR THE GRINDING ACTION OF SAND AND GRAVEL TOSSED AGAINST THE STEEP SHORES OR DRAGGED ACROSS THE BEACH; AND (3) BY SOLUTION OF SOLUBLE SHORELAND ROCKS, A VERY MINOR PROCESS. STORM WAVES WEAR AWAY WEAK STRATA CREATING CLIFFED SHORELINES IN BOTH THE UNCONSOLIDATED GLACIAL DEPOSITS SURROUNDING MOST OF LAKE MICHIGAN AND THE ROCKY COASTS OF VARIOUS PARTS OF THE GREAT LAKES SHORELINES.

Where waves break at the bases of cliffed shorelines, notching occurs and cave-like erosional features can develop. Cliff retreat is then hastened by the collapse of the overhanging rocks and sediments and rapid retreat becomes a major concern. Man has committed these cliff surfaces to residential and other uses such that the very natural processes of shoreline erosion at high lake levels now arouse public pressure to alter the natural system, to control shoreline erosion. This concern is the subject of a subsequent chapter.

Dunes

Beaches are actually transition zones between the lake environment and the wind-dominated environment of the dunes. The portion of the beach nearest the water is subjected to wave wash and spray much of the time and consists mostly of the larger sized materials such as coarse sand, gravel, and flattened pebbles or shingle gravels. Further inland, near the toe of the foredune, water plays less and less a role in shaping the beach. Wind is the controlling force here as can be seen by the numerous sand ripples (very similar in appearance to the ripples produced by wave and current action in the lake). Eventually these ripples combine to form dunes.

Away from the surf zone, the grain size and mineralogic composition of the sand change also. The wind is less capable of moving more massive objects than is the water, thus the larger, heavier sand particles remain on the forebeach while the fine sand is carried inland to form sand ripples and eventually dunes. Also, the sand inland contains fewer grains of the higher density minerals such as magnetite, garnet, and zircon. The transition from the water to the wind environment on the beach is a subtle one as the air and water systems blend imperceptibly into one another.

The first stage in dune formation is the movement of individual sand grains by wind. There are three ways by which wind moves sand: most commonly there is a simple rolling along of the grains, but if the wind is somewhat stronger, the grains are moved by a process called saltation, a jumping action where the sand particles collide with one another imparting momentum in each collision. In storm winds the sand is actually picked up and borne on the wind, sometimes for distances in excess of 100 years before falling back to the ground. Other factors, such as the shape, density, size, and surface texture of the grains, also affect the mechanism and rate of sand transport.

Ripples are the first features to form. They include all variations of the sand surface due to ruffling by wind and commonly consist of small wavelike ridges having gentle windward and steep lee slopes. Local wind oscillations also generate ripples on the lee side of sticks and stones. Wind speeds of about 7 miles per hour are most conducive to

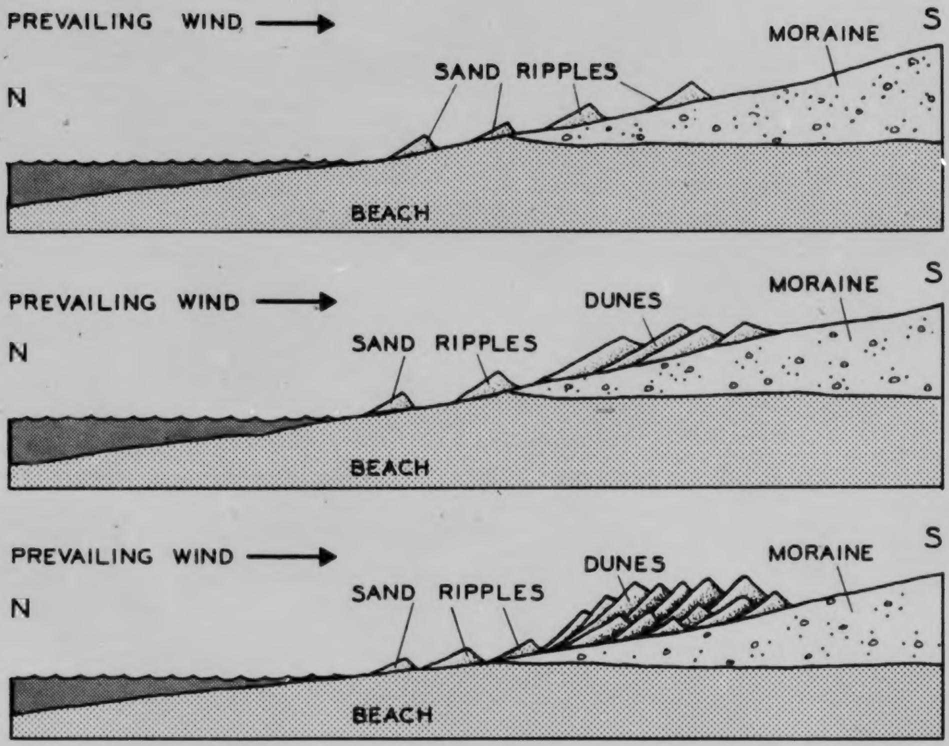
PREVAILING WIND
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FIGURE 17. BEACH RIPPLE TO SAND DUNE EFFECT.

RIPPLE FORMATION. THE RIPPLES DISAPPEAR AND THE SAND IS BLOWN IN SHEETS OR STREAMERS AT WIND SPEEDS IN EXCESS OF 20 MILES PER HOUR. THOUGH ON A MUCH LARGER SCALE, DUNES FORM BY MECHANISMS SIMILAR TO THAT FOR RIPPLES. DUNE FORMATION IS BROUGHT ABOUT BY ONLY TWO BASIC PROCESSES, ALTHOUGH VARIATIONS ARISE IN EACH PROCESS. FIGURE 17 ILLUSTRATES THE PROCESS INVOLVING THE OVERTAKING OF LARGER RIPPLES BY SMALLER ONES. DUNES ALSO FORM BY THE CHECKING OF THE SAND-LADEN WIND BY SOME OBSTACLE, SUCH AS VEGETATION, THEREBY REDUCING ITS CARRYING CAPACITY AND RESULTING IN DEPOSITION OF SAND. THE MOST COMMON MODE OF FORMATION IS THE OBSTRUCTION OF MOVING SAND BY VEGETATION.

WHEN MOVING SAND IS CHECKED BY GRASSES OR TREES, SOME IS DEPOSITED TO FORM A LEE DUNE BEHIND THE OBSTACLE. LEE DUNES ARE COMMON IN THE LAKE MICHIGAN AREA AND RANGE IN SIZE FROM A FEW INCHES HIGH AND A FOOT OR SO LONG TO HEIGHTS OF OVER 10 FEET AND LENGTHS OF 25 FEET OR MORE. AS THE WIND SHIFTS DIRECTIONS, THE TAILS OF THE LEE DUNES ARE ALSO TURNED SO THAT THEY ARE UNDER THE PROTECTING LEE OF THE OBSTACLES. ON THE OPEN SURFACES OF HIGHER DUNES, THE SAND ACCUMULATIONS ABOUT CLUMPS OF VEGETATION LOSE THEIR TAILS AND BECOME CONICAL. THESE ARE CALLED TURRET DUNES.

The first dunes to form in the transition zone of the upper beach are the foredunes. They evolve on wide flat beaches where there is an abundant supply of sand and effective onshore winds. The linear character of the foredune complex is due partly to the influence of the lake winds and to the belt of vegetation that springs up beyond the beach margin, but mostly to the sand supply. While the sand supply is abundant and the beach remains the same width, the foredune ridge continues to grow in height and width. After a maximum elevation is reached, however, the wind carries sand away as rapidly as it can be brought up the windward slope. Usually, the upper limit of foredunes is about 50 to 75 feet, though some foredunes have been known to reach heights of 100 feet. The windward slope of the foredune is usually about 10°, whereas the lee slope stabilizes at 30°.

Blowouts

Blowouts begin as small channels excavated by the wind in older dunes. The excavated area enlarges to the size of great amphitheaters whose concave sides face windward. Blowouts range from a few feet to as much as several hundred years in width; in length, to a quarter of a mile; and in height, to a maximum of about 200 feet.

Blowouts are most commonly found in the older, well-established foredunes because the surface is stabilized by well-entrenched vegetation so that when cutting begins it is confined to a narrow and relatively deep channel. More recently formed foredunes, with little protective vegetation, often exhibit broad scour zones that do not develop into large blowouts.

Interdunal Areas

The area that lies between the successive dune and beach ridge complexes of successive shorelines is referred to as an interdunal region. It is generally characterized by swamps, ponds, and lee type dunes. For example, three interdunal areas exist along the south shore of the lake. They occur between the Glenwood and Calumet dunes, the Calumet and Toleston dunes, and the Toleston and younger dunes. In that area only the interdunal area between the Toleston and younger dunes has the classic freshwater marsh and accompanying aquatic vegetation.

The reason for the dominance of wetland behind the modern foredunes is the presence of a high water table. Near the lake, the groundwater table in the dunes is directly connected to the lake. The surface of the water table tends to rise and fall with the landscape as a subdued replica of the surface topography. However, within the first several hundred years of the lake the surface of the groundwater table is nearly the same as the lake level.

Wind blowing across the interdunal area strips away the sand in some areas until the elevated portion of the groundwater table is intersected. Where the water table is breached, the surface sand is saturated and, consequently, not readily removable by wind. Thus, wind erosion in the interdunal area is limtied by the elevation of the local water table. Minor fluctuations in water table elevation combined with ensuing wind scour results in numerous interdunal ponds and marshes. Maintained by the water table, these ponds provide a perpetual habitat for a variety of unusual flora and fauna that are unique to this part of the Midwest.

An additional focus of this introductory chapter on the Lake Michigan area centers on the human occupance and the evolution of the current land use conflicts and opportunities in an effort to understand the cultural setting within which natural resources utilization is occurring. Settlement of the area was guided by both the advantages and disadvantages of the landscape for various kinds of development and, thus the geomorphology or physiography has had a great influence over the sequence of human activities.

The natural setting established a framework of both restraints and opportunities for early human occupance and the ensuing diversified settlement which has culminated in the dynamic and often controversial nature of the region's present land uses. Thus, two distinctive stages of this human occupance occurred.

The first was an early but very long phase lasting almost until the mid-Nineteenth Century; during this time, man's activities were adapted to the constraints of the natural environment to satisfy demands for agricultural, industrial and residential land uses. Earliest known inhabitants were Indians who traversed the area for many millenia following the melting and recession of the glaciers some 14,000 years ago and the concurrent earliest inception of ancestral Lake Michigan. Indications point to man's having occupied this region as early as 12,000 years ago (Archaic Period). This period of occupance and existence persisted until about 3,000 years ago. The Archaic inhabitants were hunters, fishermen, and gatherers, and they experienced profound climatic, geologic, and biologic changes in their environment.

The Archaic Period is followed by the Woodland Period consisting of early (2500-200 BC), middle (200 BC-500 AD) and lake phases (500 AD - 1700 AD) lasting from 2,500 years ago until European contact.

Early Woodland tribes introduced pottery; not much information is available about the mid-Woodland tribes, but the late Woodland culture introduced some forms of agriculture to the Great Lakes region about 600 AD. Here, subsistence patterns involved hunting, gathering and fishing and persisted even into the period of the European presence. Among these tribes were the Ottawa, Miami, Wea, and eventually, the Potawatomie Indians.

The environmental impact of the Indians and later, the fur traders was neither extensive nor damaging. There is no report of the game being over hunted; fires running destrictively out of control; nor major imprints being made from villages. The white man who moved into the area in the 1830's did not encounter an untouched landscape, but it was a landscape which bore more the imprint of nature than of man.

This situation changed quickly as the area was opened for settlement during the 1830's and came into private ownership of a new culture group. This later stage of land use is characterized by extensive modification of the topography and drainage, the flora and fauna, and an ever increasing exploitation of the natural resources. Pioneer settlement began as isolated farmsteads and trading posts and hunting and trapping lodges. This stage of occupancy involved few changes by man of the natural environment. Increased occupancy and the changing use of the area with time, however, has greatly transformed the original appearance of the landscape from a natural to a man made one. The fate of the area was decided with the arrival of the railroads in the 1850's and the establishment of the first major industries.

Today, culmination of more than 12,000 years of human occupance in the Lake Michigan area finds a dynamic pattern of conflicting land uses. Competition exists over the same lands (and waters) for industrial, commercial, recreational, residential, and conservational-preservational uses. Settlement history and land use development in the United States has resulted today in the creation of large, intensively developed urban corridors; megalopolii, a merging of cities and suburbs into a continuous belt of highly developed lands which are heavily populated. Four such corridors are developed at the water's edge in the United Stages: 1) The Atlantic coast from Boston to Washington or Richmond; 2) the coast of Florida; 3) the California coast from San Francisco to San Diego, and 4) the fresh-water coast of the southern shores of the Great Lakes. Lake Michigan's borderlands from Milwaukee south to Chicago and east to Michigan is an integral urban part of this 4th coastal megalopolis. A categorization of competing land and water uses in this Lake Michigan coastal zone includes at least the following:

1) Industrial development and expansion, especially heavy industry dependent upon the utilization of large volumes of water as a constituent in industrial processes, as a cleansing agent, as a cooling medium, and for transportation of raw materials and finished products;

2) COMMERCIAL ENTERPRISE, PRIMARILY AS PUBLIC, COMMERCIAL PORTS AND THE MANY ANCILLARY FACILITIES AND SERVICES RELATED TO SUCH PORTS AND THEIR EXPANSION FOR DEEP-DRAFT VESSELS;

3) ELECTRIC POWER GENERATION, INCLUDING PLANT SITING, DEVELOPMENT, AND OPERATION OF BOTH FOSSIL-FUELED AND NUCLEAR-POWERED FACILITIES, AND THE VARIETY OF ANCILLARY LAND USES SUCH AS FUEL STORAGE, WASTE DISPOSAL, TRANSMISSION LINES AND COOLING TOWERS;

4) RESIDENTIAL DEVELOPMENTS, INCLUDING BOTH LOW AND HIGH DENSITY PRIMARY RESIDENTIAL AREAS AS WELL AS SECONDARY SUMMER OR VACATION RESIDENCES OFTEN LOCATED AT THE VERY EDGE OF THE COAST, CONTRIBUTING TO THE RAPIDLY EXPANDING POPULATION OF ENTIRE COASTAL ZONES (CITY AND SUBURBS) IN WHAT HAVE BEEN TERMED MEGALOPOLII STRETCHING FOR HUNDREDS OF MILES OF CONTINUOUS DEVELOPMENT WITH FEW INTERVENING AREAS OF OPEN SPACE;

5) TRANSPORTATION FACILITIES AND ROUTES, INCLUDING LAND, WATER AND AIR TRAVEL COMPONENTS;

6) PUBLIC SERVICES FACILITIES, INCLUDING WATER SUPPLY AND TREATMENT, SOLID AND LIQUID WASTES TREATMENT FACILITIES, AND ULTIMATE DISPOSAL SITES;

7) RECREATIONAL FACILITIES, INCLUDING WATER RELATED ACTIVITIES SUCH AS SWIMMING, FISHING, BOATING, AND SUNBATHING, AND SHORE RELATED ACTIVITIES INCLUDING HIKING, BICYCLING, HORESBACK RIDING, BACK PACKING, PICNICING, CAMPING, ETC.; AND,

8) NON-DEVELOPMENT AREAS, IN ESSENCE, SANCTUARIES FOR ENVIRONMENTALLY FRAGILE AREAS OF WATER AND LAND, NECESSARY FOR CONTINUATION OF NATURAL PROCESSES, ESPECIALLY IN ESTUARIES, TIDAL MARSHES, AND OTHER WETLANDS SUCH AS BOGS AND SWAMPS.

ALL OF THE ABOVE COMPETING LAND AND WATER USE DEMANDS OCCUR IN A NATURAL ENVIRONMENT CHARACTERIZED BY DYNAMIC PHYSICAL AND BIOLOGICAL PROCESSES. THE COASTAL ZONE IS A HIGH ENERGY ENVIRONMENT IN TERMS OF WEATHER, SHORELINE EROSION, TRANSFER AND DEPOSITION OF SEDIMENTS, AND FLOODING AND DRAINAGE. IT IS AN ENVIRONMENT PRESENTING MANY AS YET UNSOLVED ENGINEERING PROBLEMS RELATED TO HUMAN OCCUPANCE AND USE, ESPECIALLY IN LIGHT OF OUR STILL RUDIMENTARY KNOWLEDGE OF THE NATURAL-PHYSICAL PROCESSES TAKING PLACE IN THE COASTAL AIR-WATER-LAND ECOSYSTEM. IN ADDITION, THE LAND, WATER AND AIR IN THE COASTAL ZONE, IS THE HABITAT FOR A GREAT DIVERSITY AND LARGE POPULATIONS OF PLANTS AND ANIMALS. ENVIRONMENTAL CONCERNS FOR BOTH NATURAL ECOSYSTEM STABILITY AND FOR PRESERVATION OF SPECIES DIVERSITY HAVE INTENSIFIED CONCURRENT WITH A GROWING NATIONAL CONCERN FOR ENERGY SELF-SUFFICIENCY AND FOR THE CONTINUED ECONOMIC GROWTH AND DEVELOPMENT IN THE LAKE MICHIGAN COASTAL ZONES.

IN SHORT, THE COMPETITION FOR LAND USE, THE DEMANDS FOR PRESERVATION OF NATURAL ECOSYSTEMS, THE DEMANDS FOR DEVELOPMENT OF ENERGY RELATED ENTERPRISES, THE DEMANDS FOR private homes along the water's edge, the demands for recreational areas, all come together in the coastal zone because of its unique varied use potential. Ideally, these conflicts should be resolved through a systematic identification and assessment of the area's many resources, i.e., a coastal zone management plan. After fully considering the diversified social and economic demands, and after making use-suitability determinations, a comprehensive plan to attain the optimal mix of varied demands should be formulated. For the last century there was no such plan and the conflicts over land-use have raged more or less continuously. Fortunately, today legislators are coming to grips with the problem and Wisconsin and Michigan have adopted coastal zone management plans; Indiana and Illinois are still in the coastal planning process, but the future looks bright.

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41

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GLOSSARY

DOWNWELLING: a vertical flow of water downward in a lake resulting in a general depression of the colder, deeper water by warmer, wind-driven, surface water.

EPILIMNION: the region of a lake characterized by warm, freely circulating surface waters with small but variable temperature gradients.

HAZARDOUS SUBSTANCE: any gas, liquid, or solid that poses a substantial, present or potential, threat to life.

HYDROLOGIC CYCLE: a group of processes which bring water into a basin and remove water from a watershed.

HYPOLMNION: a deep, cold region of a lake that remains relatively unaltered by surface heating. Located below the thermocline.

LONGSHORE FLOW: the movement of a band of water parallel to the shoreline.

OVERTURN: a process occurring in spring and fall as a result of the uneven heating or cooling of surface waters and resulting in a uniform mixing of lake waters.

THERMAL STRATIFICATION: the division of a lake into zones based on temperature differences with changes in depth.

THERMOCLINE: a narrow band of water in a lake marked by a very rapid decline in temperature with depth.

SEICH: the alternate rise and fall of epilmnion and thermocline waters on opposite shores of a lake due to prolonged, directional wind flows.

UPWELLING: the physical removal of surface waters by wind action which results in a rise of cold, deep waters to the surface of a lake.

LAKE DYNAMICS AND HYDROLOGY

An accurate assessment and ultimate improvement of Great Lakes water quality is dependent upon several factors. Perhaps the most important of these factors is a clear understanding of the physical processes which control the dynamics of lake circulation and hydrology. Before investigating these physical processes in operation in the Great Lakes, let us spend a few moments defining some terminology. Dynamics is the study of the action of forces on bodies either at rest or in motion. Hence, lake dynamics is the study of all physical forces which operate on, in or above the Great Lakes. Similarly, hydrology is the study of fluid motion into and out of bodies of water. The hydrologic cycle is the term given to the group of processes which bring water into and remove water from the Great Lakes Basin. These transports may take many forms, such as precipitation, ground water and riverine flows into the basin, evaporation from the watershed and lake surfaces, and evapotranspiration from terrestrial vegetation. Hence, the net balance of these inputs and outflows results in the water levels experienced in the Great Lakes.

Nearly all chemical, biological and geological processes which occur in the Great Lakes are affected to some degree by the dynamics of lake circulation. The distribution of chemical contaminants as well as specific nutrients are governed by the physics of lake circulation. Similarly, the migration and lateral distribution of algae and other planktonic (floating) organisms are controlled by lake currents and the general thermal structure of the water body.

Perhaps the interaction of geological processes with physical processes along the perimeter of the Lakes provides the most vivid examples of this interdependency. Shorelines of the Great Lakes as well as the oceans are continually being altered and molded by coastal erosion. Storm generated waves, which attack the shoreline, cause beach sediment to go into suspension, making it available for transport along the coastline. This longshore transport of beach material results in areas of erosion as well as areas of deposition along the Great Lakes shorelines. The severity of coastal erosion is dependent upon the intensity and frequency of severe storms as well as the relative water level of the

LAKES. YEARS IN WHICH PRECIPITATION AND RUNOFF INTO THE LAKES EXCEED EVAPORATION FROM THE BASIN, LAKE LEVELS RISE. DURING THESE YEARS OF HIGH WATER, STORM WAVES CAN ATTACK DIRECTLY AT THE BASE OF COASTAL DUNES, RESULTING IN RAPID COASTAL EROSION. THIS BEACH MATERIAL, MADE AVAILABLE BY WAVE ACTION AT THE SHORE, CAN NOW BE TRANSPORTED BY COASTAL CURRENTS. CONVERSELY, DURING YEARS OF LOW WATER LEVELS, DUNE AND BLUFF AREAS ARE PROTECTED FROM DIRECT WAVE ATTACK BY A WIDE SAND BEACH AND COASTAL EROSION IS MINIMIZED.

A CLEARER UNDERSTANDING OF THE PHYSICAL PROCESSES INVOLVED IN LAKE DYNAMICS AND HYDROLOGY IS THE KEY WHICH WILL UNLOCK THE GATE TO SUPERIOR WATER QUALITY IN THE GREAT LAKES. A GENERAL WORKING KNOWLEDGE OF THE WIND DRIVEN SURFACE CIRCULATION, THE THERMAL STRUCTURE AND ITS ASSOCIATED CIRCULATIONS, THE FLOW OF WATER INTO AND OUT OF THE GREAT LAKES AND THE INTERACTIONS OF THESE PROCESSES IN THE COASTAL ZONE IS IMPORTANT TO ALL CONCERNED CITIZENS OF THE GREAT LAKES BASIN.

THE GENERAL CIRCULATION OF LARGE LAKES, SUCH AS THE GREAT LAKES, IS A VERY COMPLEX PROBLEM AND ONE THAT IS NOT COMPLETELY UNDERSTOOD. THE ENERGY SOURCE WHICH DRIVES THE CIRCULATION OF LARGE BODIES OF WATER COMES ULTIMATELY FROM THE SUN. SOLAR ENERGY CAN BE MANIFESTED IN SEVERAL FORMS OF LAKE CIRCULATION. VARIATIONS IN SURFACE HEATING OVER THE EARTH RESULTS IN PREVAILING WIND PATTERNS. THESE WIND FIELDS, WHICH, IN THE LATITUDES OF THE GREAT LAKES, ARE THE PREVAILING WESTERLIES, AND ARE RESPONSIBLE FOR THE GENERATION OF THE GENERAL SURFACE CIRCULATION OF THE LAKES.

THE CLIMATE OF THE GREAT LAKES BASIN IS TYPICAL OF MID-CONTINENTAL REGIONS WITH A HARSH WINTER AND WARM SUMMER. THIS CLIMATE IS MODIFIED SOMEWHAT BY THE PRESENCE OF THE LARGE VOLUMES OF WATER ASSOCIATED WITH THE GREAT LAKES. THE GREAT LAKES LIE BETWEEN SOURCE REGIONS OF CONTRASTING POLAR AND TROPICAL AIR MASSES. THE FRONTAL INTERSECTION OF THESE TWO AIR MASSES RESULTS IN THE GENERATION OF CYCLONIC STORMS WHICH MOVE THROUGH THE GREAT LAKES REGION UNDER THE INFLUENCE OF THE PREVAILING WESTERLIES. THE NUMEROUS AND RAPID CHANGES IN WEATHER CONDITIONS EXPERIENCED IN THE GREAT LAKES REGION ARE A RESULT OF THE PASSAGE OF THESE STORM SYSTEMS THROUGH THE AREA. HENCE, ALTHOUGH WESTERLY WINDS PREVAIL, TRANSIENT WINDS FROM ANY DIRECTION MAY BE ENCOUNTERED AS STORMS PASS.

LARGE QUANTITIES OF SOLAR ENERGY ALSO ARE DIRECTLY ABSORBED BY WATER BODIES. AS SOLAR ENERGY IS ABSORBED, IT IS TRANSFORMED INTO HEAT AND THUS THE TEMPERATURE OF THE WATER BODY RISES. THIS GIVES RISE TO THE THERMAL STRUCTURE OF THE WATER BODY AND RESULTS IN CIRCULATIONS DRIVEN BY DENSITY DIFFERENCES INDUCED BY NONUNIFORM HEATING OF THE WATER.

IT IS IMPORTANT TO RECOGNIZE THAT INDEPENDENT OF WHETHER LAKE CIRCULATION IS INITIATED BY A WIND STRESS APPLIED AT THE SURFACE OR BY THE VARIATIONS IN THE FIELD OF MASS WITHIN THE WATER BODY, WATER IS IN MOTION AT ALL DEPTHS OF THE LAKES. BUT THESE CURRENTS ARE PRODUCED AND MAINTAINED BY CONDITIONS EXISTING IN A VERY THIN SURFACE LAYER. IT IS THEREFORE OF PRIME IMPORTANCE TO INVESTI-

GATE THE MECHANICS IN OPERATION AT THE AIR-SEA INTERFACE.

THE GENERAL WIND DRIVEN SURFACE CIRCULATION OF A BODY OF WATER RESULTS PRIMARILY FROM AN INTERACTION BETWEEN THE WIND AND WATER AT THE AIR-SEA INTERFACE AND THE GEOMETRY OF THE LAKE BASIN. AS WIND BLOWS ACROSS THE WATER SURFACE, MOMENTUM FROM THE WIND IS TRANSFERRED INTO THE FLUID. IN ADDITION TO GENERATING SURFACE WAVES, A PORTION OF THIS MOMENTUM IS AVAILABLE TO CAUSE FLUID MOTION IN THE GENERAL DIRECTION OF THE WIND. IF THE DIMENSIONS OF THE BODY OF WATER ARE SUFFICIENTLY LARGE, THE EFFECTS OF THE EARTHS' ROTATION MUST BE INCORPORATED INTO THE PREDICTION OF LAKE CIRCULATION. THE EFFECT OF THE EARTH'S ROTATION (CORIOLOS EFFECT) IS TO PRODUCE A DEFLECTION OF SURFACE WATER TO THE RIGHT OF THE WIND IN THE NORTHERN HEMISPHERE. (FIGURE 1.)

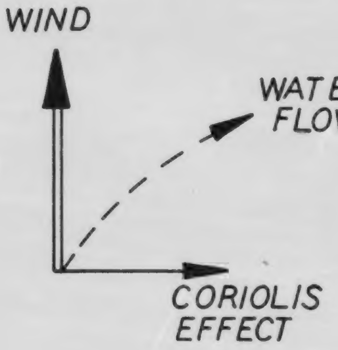

FIGURE 1. THE FLOW OF WIND DRIVEN SURFACE WATER UNDER THE INFLUENCE OF CORIOLIS DEFLECTION.

BECAUSE WATER IS A VISCOUS FLUID, THE FRICTIONAL STRESS RESULTING FROM THE WIND BLOWING ACROSS THE SURFACE, WILL BE TRANSMITTED DOWNWARD. THIS TRANSFER OF MOMENTUM IS A TURBULENT PROCESS IN BOTH THE GREAT LAKES AS WELL AS THE OCEAN. THEREFORE, AS BOTH THE DURATION THE WIND HAS BLOWN AND THE SPEED OF THE WIND INCREASE, THE SPEED AND DEPTH OF PENETRATION OF THE SURFACE CURRENT ALSO INCREASE. THIS GROWTH PROCESS CONTINUES UNTIL AN EQUILIBRIUM IS REACHED IN THE MOMENTUM TRANSFER FROM THE WIND TO THE LAKE SURFACE. WHEN THE WIND STOPS, OR CHANGES DIRECTION, THE WATER WILL SLOWLY RESPOND TO THIS CHANGE, RE-ESTABLISHING A NEW EQUILIBRIUM.

SINCE ATMOSPHERIC CONDITIONS IN THE REGION OF THE GREAT LAKES ARE EXTREMELY VARIABLE, WITH SURFACE WIND CONDITIONS CHANGING RAPIDLY, COMPLETE EQUILIBRIUM BETWEEN WIND AND SURFACE CURRENTS IS SELDOM ATTAINED. THE SURFACE CURRENT PATTERNS OF THE GREAT LAKES EXHIBIT LARGE VARIABILITY FROM SEASON TO SEASON AS WELL AS DAY TO DAY. NEVERTHELESS, MEAN CURRENT MAPS OF THE GREAT LAKES ARE AVAILABLE (SEE FIGURE 2). IT SHOULD BE NOTED, HOWEVER, THAT THESE CURRENTS ARE LONG TERM AVERAGE CURRENTS. THESE CURRENT CHARTS ARE NOT INTENDED FOR NAVIGATION PURPOSES. AT ANY GIVEN TIME THE POSITION OF THE CURRENT AND ITS STRENGTH MAY BE SIGNIFICANTLY DIFFERENT FROM THE AVERAGE VALUE.

INTENSIFICATION OF THE GENERAL WIND DRIVEN CIRCULATION CAN OCCUR NEAR THE BOUNDARIES OF THE GREAT LAKES. THE TRANSPORT OF SURFACE WATER TOWARD THE SHORELINE MAY RESULT IN THE GENERATION OF A COASTAL BOUNDARY LAYER. THIS COASTAL ZONE OF APPROXIMATELY 10 KM WIDTH, CAN BE DEFINED AS THE BAND OF WATER WITHIN WHICH PERSISTENT LONGSHORE FLOW (PARALLEL TO THE SHORELINE) DOMINATES (CSANADY, 1975). IN COASTAL WATERS, ONSHORE WIND DRIVEN

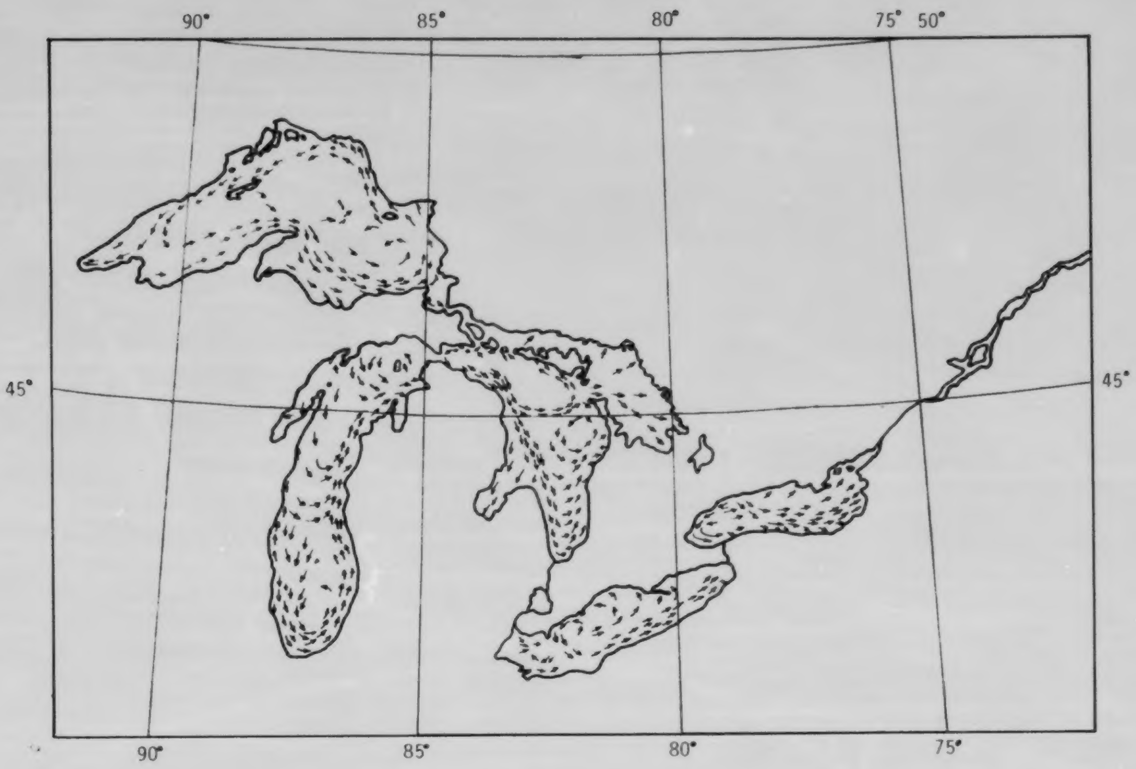
90°
85°
80°
75°
50°
45°
45°
90°
85°
80°
75°

FIGURE 2. MEAN SURFACE CIRCULATION OF THE GREAT LAKES (FROM MILLAR, 1952).

TRANSPORT OF WATER IS PROHIBITED BY THE GEOGRAPHIC BOUNDARIES OF THE LAKE. THIS CONSTRICTION RESULTS IN AN ACCELERATION OF WATER ALONG SHORE. THE NET OUTCOME IS THE GENERATION OF NARROW, HIGH VELOCITY FLOWS KNOWN AS COASTAL JERKS. CSANADY AND SCOTT (1974) HAVE REPORTED THAT RAPID FLOW REVERSALS ARE COMMON TO THESE FLOW FIELDS, THUS CAUSING RAPID AND SIGNIFICANT DEPARTURES FROM THE EXPECTED MEAN (AVERAGE) CURRENT CIRCULATION IN THE COASTAL ZONE.

IN REGIONS OF STRONG HORIZONTAL COASTAL CIRCULATIONS SUCH AS COASTAL JETS, SIGNIFICANT VERTICAL CIRCULATION MAY BE INDUCED. WHEN SURFACE WATER IS TRANSPORTED TOWARD A COASTLINE A TEMPORARY PILING-UP OF FLUID

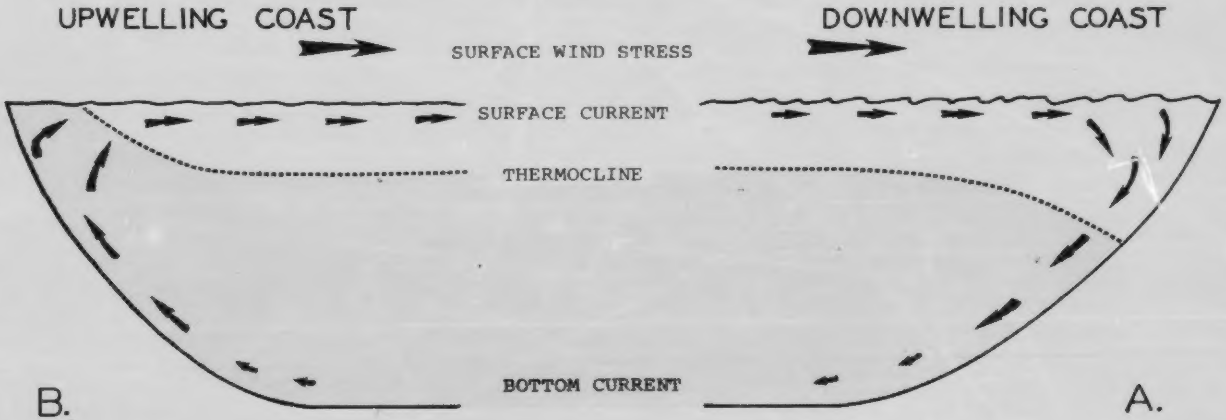
UPWELLING COAST
DOWNWELLING COAST
SURFACE WIND STRESS
SURFACE CURRENT
THERMOCLINE
BOTTOM CURRENT
B.
A.

FIGURE 3. CIRCULATION ASSOCIATED WITH AN "UPWELLING" AND "DOWNWELLING" COAST.

AGAINST THE SHORELINE MAY RESULT. IN AN EFFORT TO RETURN TO A STATE OF EQUILIBRIUM, A VERTICAL FLOW OF WATER DOWNWARD CAN OCCUR. THIS SITUATION, TERMED "DOWNWELLING" RESULTS IN A GENERAL DEPRESSION OF THE COLD DEEPER LAKE WATER WHICH IS REPLACED BY WIND DRIVEN WARM SURFACE WATER (FIGURE 3A). THE POSITION OF THE THERMOCLINE, THE DIVISION BETWEEN WARM SURFACE WATER AND COOLER, DEEPER WATER MASSES, IS A GOOD INDICATOR OF VERTICAL CIRCULATION. AS FLUID IS FORCED DOWNWARD NEAR THE COAST, AN OFFSHORE FLOW SHOULD BE ANTICIPATED ALONG THE LAKE BOTTOM. THIS OFFSHORE FLOW OF BOTTOM WATER CAN BE SUFFICIENTLY INTENSE TO TRANSPORT NUTRIENTS, POLLUTANT AND FINE GRAIN SUSPENDED SEDIMENT TO THE DEEPER PORTIONS OF THE LAKE.

SIMILARLY, WHEN SURFACE WATER IS DRIVEN AWAY FROM THE COASTLINE, AN "UPWELLING" CAN OCCUR (FIGURE 3B). THE UPWELLING IS CHARACTERIZED BY GENERAL RISE IN THE THERMOCLINE, BRINGING COLD DEEPER WATER TO THE SURFACE, A GENERAL ENRICHMENT OF THE COASTAL WATER BY NUTRIENTS BROUGHT UP FROM DEPTH AND A GENERAL ONSHORE FLOW OF BOTTOM WATER. AN UPWELLING GENERALLY INHANCES BIOLOGICAL ACTIVITY IN THE REGION.

GENERALLY, IN BODIES OF WATER OF THE DIMENSIONS OF THE GREAT LAKES, UPWELLINGS AND DOWNWELLINGS OCCUR NEARLY SIMULTANEOUSLY ON OPPOSITE SIDES OF THE BASIN. WHEN THE BASIN IS SUBJECTED TO A STRONG WEST WIND, FOR EXAMPLE, DOWNWELLING WILL OCCUR ALONG THE WINDWARD OR EAST COAST OF THE BASIN AND A CORRESPONDING UPWELLING WILL BE EXPERIENCED ALONG THE LEEWARD OR WEST COAST OF THE LAKE.

ONCE THE WIND HAS SUBSIDED, THE LAKE MAY FREELY OSCILLATE FROM SIDE TO SIDE. THIS RESULTS IN ALTERNATE RISES AND DEPRESSIONS OF BOTH THE SURFACE AND THERMOCLINE OCCURRING ON OPPOSITE SHORES. MOTION OF THIS TYPE, KNOWN AS SEICHING, WILL SLOWLY DAMP OUT, BUT MAY PERSIST FOR SEVERAL DAYS FOLLOWING A MAJOR STORM EVENT. SEICHES, WHICH ARE SIMILAR IN MANY WAYS TO THE SLOSHING OF A BATH TUB, HAVE ATTAINED AMPLITUDES AS LARGE AS SEVERAL FEET ON THE GREAT LAKES.

IN ADDITION TO WIND GENERATED WATER MOTIONS, WATER MAY ALSO BE SET INTO MOTION, AND CURRENTS GENERATED, BY FORCES RELATED TO THE RELATIVE MASS PER UNIT VOLUME OF WATER. THESE FORCES ARE MOST OFTEN EXPRESSED IN TERMS OF THE SPECIFIC GRAVITY, DENSITY OR PRESSURE OF THE WATER. THESE FORCES ARE MAINTAINED BY THE ANNUAL THERMAL CYCLE OF THE GREAT LAKES.

RELATIVELY LARGE AND DEEP LAKES IN TEMPERATE CONTINENTAL CLIMATE REGIONS, SUCH AS THE GREAT LAKES, EXHIBIT STRONG RESPONSE TO SEASONAL TEMPERATURE VARIATIONS. DURING THE LATE WINTER SEASON THE GREAT LAKES ARE NEARLY THERMALLY HOMOGENEOUS FROM THE SURFACE TO THE BOTTOM. AS THE SEASONS PROGRESS INTO SPRING, THE LAKES BEGIN TO WARM FROM THE SURFACE DOWNWARD. AS WARMING CONTINUES THE LAKE SLOWLY BECOMES STRATIFIED WITH A WELL MIXED, BUT SHALLOW SURFACE LAYER CALLED THE EPILIMNION. BELOW THE THERMOCLINE, THE WATER OF THE DEEP, COLD PORTIONS OF THE LAKE, THE HYPOLIMNION, REMAINS ALMOST TOTALLY UNALTERED BY HEATING OF THE LAKE AT THE SURFACE. THUS, THE THERMOCLINE ACTS AS A BARRIER BETWEEN WARM, BIOLOGICALLY ACTIVE SURFACE WATER AND COLD, DORMANT DEEP LAKE WATER.

As surface heating of the lake continues through the summer months, the thermocline intensifies and deepens as the epilimnion warms and thickens (Figure 4A). Throughout all seasons, however, the water of the deep portions of the lake remains almost totally unaltered at approximately 4°C. In the autumn as ambient temperatures begin to fall, the lake begins to slowly give up to the atmosphere, the heat stored during the warm months. As heat is lost, the thermocline becomes weaker and deeper. This process continues until the thermocline finally disappears, and the lake once again becomes thermally homogeneous. If cooling is sufficiently intense to allow freezing in winter, inverse stratification may be established below the ice cover. That is, ice existing at the surface implies temperatures less than 0°C. Under these conditions, temperatures generally increase with depth into the lake until once again the deep lake water is reached with a temperature of approximately 4°C (Figure 4B).

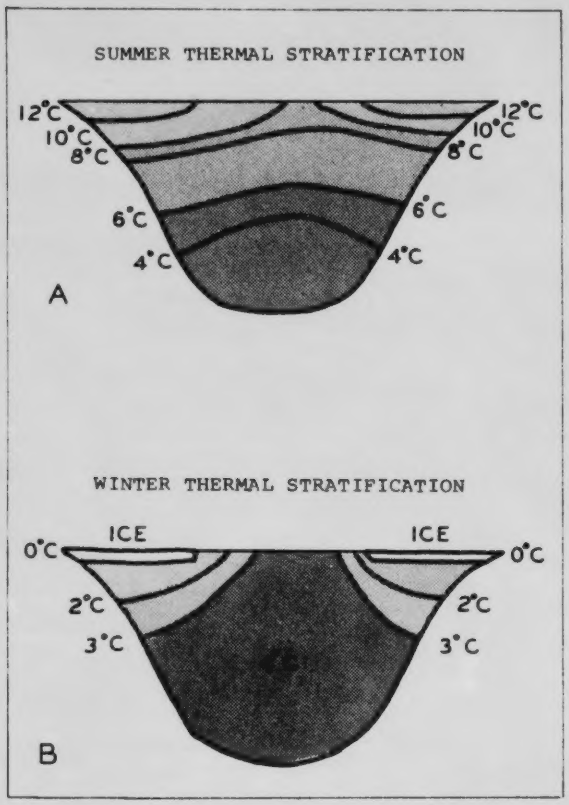

FIGURE 4. Typical summer and winter thermal stratification of the Great Lakes.

The deep lake water of large fresh water lakes remains at a temperature near 4°C due to several peculiar peoperties of the water molecule. Unlike most substances, pure water attains its maximum density at approximately 4°C. Hence, water both warmer and colder than 4°C will be less dense than water at 4°C. If it were not for this anomalous behavior, life as we know it would not exist. Lakes would freeze from the bottom up and most likely freeze solid during the winter. With the ice phase of water being less dense than the liquid phase, at slightly higher temperatures, ice freezes at the surface of lakes and forms a "protective lid" which resists further heat loss from the lake. Once ice has formed, the rate of cooling is severely retarded and the majority of the lake remains relatively warm throughout even the most harsh winters.

Water attaining its maximum density near 4°C gives rise to density driven circulations in the Great Lakes. During the fall cooling period and the early spring warming period, the surface water may attain a temperature of 4°C. When this occurs, the water column is said to be gravitationally unstable. Heavier 4°C water will seek a new equilibrium at greater depth in the lake with fluid from below moving to replace the sinking surface water. This process, known as overturning, is responsible for significant vertical mixing in the Great Lakes.

In addition to overturning, thermally driven circulations can play a major role in nearshore mixing processes (Huang, 1969). During the spring warming period, the temperature of the relatively shallow onshore regions rises more rapidly than the central deep portions of the lake. This can give rise to temperatures greater than 4°C near shore and temperature less than 4°C in the offshore regions. The boundary of dense 4°C water separating these two regions is called the "thermal bar".

Similarly, during the late fall cooling period, the opposite thermal condition exists. The shallow coastal regions lose heat more rapidly than the central lake regions, resulting again in the formation of a thermal bar circulation. Regardless of whether the thermal bar is formed during the heating or cooling period of the lake thermal cycle, the bar will form near the shore. As the season progresses, the bar will migrate toward the deeper portions of the lake and become less well defined. After a period of approximately four to six weeks the thermal bar will dissipate (Huang, 1969). Stoermer (1968) has shown that across the thermal bar, marked color differences, as well as differences in biological populations should be expected. It is also possible that the thermal bar may act as a barrier to the offshore transport of fine grain suspended sediment (Meadows, unpublished data).

The total amount of water that comprises the Great Lakes system is a direct result of the meteorological and climatic conditions of the area. It could hardly be expected, therefore, that water levels should remain constant. In fact, the water levels of the Great Lakes should be anticipated to vary with periods consistent with weather cycles. This observation gives rise to the study of balances between precipitation and evaporation for the Great Lake region. Within the hydrologic cycle lies the key to prediction of the Great Lakes water levels.

It has long been known that the mid-latitudes represent a battle ground between two opposing air masses. Maritime Tropical Air (M.T.A.) is formed over tropical ocean water and is characterized by warm temperatures and high humidity. This air generally sweeps northward from the Gulf of Mexico over the continental United States. On its journey northward, M.T.A. collides with outbreaks of Continental Polar Air (C.P.A.) somewhere over the North American Continent. This zone of collision develops into fronts, along which local weather systems are generated. C.P.A. originates in the northern show covered regions of Canada. These air masses are typically cold and relatively dry. It is along this frontal zone where M.T.A. is forced aloft by encroaching outbreaks of C.P.A., that intense cloud cover and precipitation are generated.

To investigate the effect of the various factors contributing to the hydrologic cycle it is useful to consider a schematic hydro-

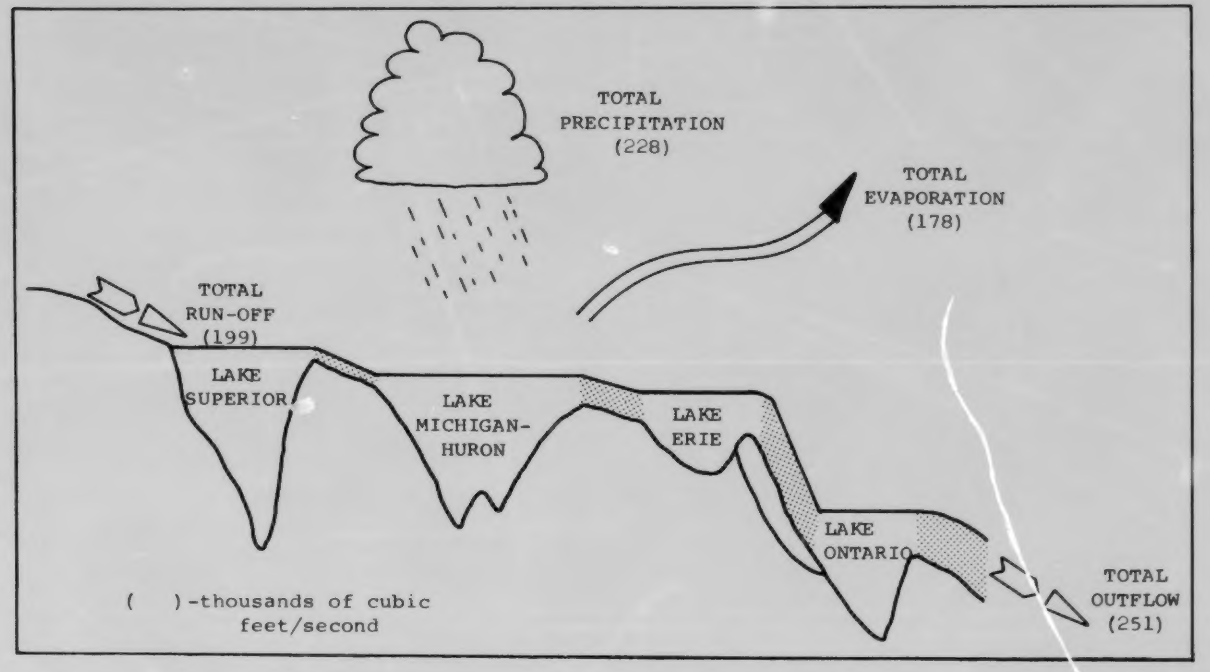

FIGURE 5. SCHEMATIC REPRESENTATION OF HYDROLOGIC BALANCE OF THE GREAT LAKES BASIN (MODIFIED FROM I.J.C. 1976).

LOGIC BALANCE FOR THE GREAT LAKES (SEE FIGURE 5). THE AIR MASS COMPRISING THE M.T.A. IS CAPABLE OF TRANSPORTING APPROXIMATELY 3 1/3 TIMES THE TOTAL AMOUNT OF WATER WHICH FALLS AS PRECIPITATION ON THE GREAT LAKES WATERSHED. ABOUT 90 PERCENT OF THE TOTAL ANNUAL RAINFALL RECEIVED BY THE GREAT LAKES BASIN, ORIGINATES FROM MOISTURE CONTAINED BY M.T.A. IN ADDITION TO PRODUCING RAINFALL, AIR MASSES IN CONTACT WITH THE GROUND INITIATE EVAPORATION FROM THE EARTH'S SURFACE. THIS OCCURS AT ALL TIMES WHEN THE RELATIVE HUMIDITY OF THE AIR IS LESS THAN 100 PERCENT. EVAPORATION OCCURS FROM THE SOIL, LAKES, RIVERS AND TRANSPIRATION FROM PLANTS INTO THE PASSING M.T.A. THE M.T.A. LEAVES THE LAKES AREA DEPLETED OF APPROXIMATELY ONE-THIRD ITS ORIGINAL WATER CONTENT.

SIMILARLY, THE COOLER AND DRYER C.P.A. ENTERS THE WATERSHED CARRYING APPROXIMATELY 1 1/2 TIMES THE TOTAL AMOUNT OF WATER WHICH FALLS AS PRECIPITATION ON THE AREA. BEING LOWER IN RELATIVE HUMIDITY, THIS AIR MASS IS CAPABLE OF ABSORBING AND TRANSPORTING LARGER QUANTITIES OF WATER VAPOR FROM THE REGION. THE TOTAL AMOUNT OF WATER ABSORBED BY C.P.A. IS SLIGHTLY LESS THAN HALF THE TOTAL ANNUAL RAINFALL OF THE REGION. THIS AIR MASS, HOWEVER, ONLY ACCOUNTS FOR ABOUT 10 PERCENT OF THE TOTAL ANNUAL PRECIPITATION. GENERALLY, THE C.P.A. LEAVES THE GREAT LAKES WITH ABOUT 30 PERCENT MORE MOISTURE THAN IT ORIGINALLY CONTAINED. EVAPORATION INTO PASSING AIR MASSES REPRESENTS A VERY SIGNIFICANT TRANSPORT OF WATER OUT OF THE GREAT LAKES SYSTEM. THIS TRANSPORT CAN BE AS LARGE AS 1/3 THE TOTAL OUTFLOW OF THE MISSISSIPPI RIVER.

HENCE, THE GREAT LAKES DRAINAGE BASIN RECEIVES ABOUT 90 PERCENT OF ITS PRECIPITATION FROM M.T.A. AND ABOUT 10 PERCENT FROM C.P.A. THE BASIN LOSES A VOLUME EQUAL TO about 45 percent of this rainfall to evaporation which is transported out of the region. The drainage of the Great Lakes through the St. Lawrence River accounts for the remaining 55 percent of water transport (Grima and Wilson-Hodges, 1977). It is important to stress, however, that the total amount of water transported by the air is about 10 times that transported by rivers and that evaporation accounts for about as much flow as the total riverine flow. The dominant source of water for the Great Lakes results from a balance of precipitation and evaporation from M.T.A. and C.P.A. over the region. As these air masses move back and forth over the Great Lakes region, water is added to and removed from the lake system. Very dry years, and low lake levels are primarily the result of greater duration of C.P.A. over the Great Lakes region. Conversely, high water levels results from M.T.A. outbreaks of long duration.

Several other factors also influence Great Lakes water levels. During severe winters which persist until a massive spring thaw, little moisture from snow is sublimated directly into the air as water vapor. Under these spring conditions, runoffs into the lakes are unusually large. In contrast, during mild winters, characterized by several thawing periods, more moisture can be evaporated directly into the atmosphere, reducing runoff into the lakes.

The relatively large storage capacity of the Great Lakes, results in a high degree of natural regulation of water levels. However, seasonal as well as longer period water level variations are prevalent. Long-period cycling of lake levels is not a well understood phenomena, however, these periods do appear to correspond to long term climatic fluctuations.

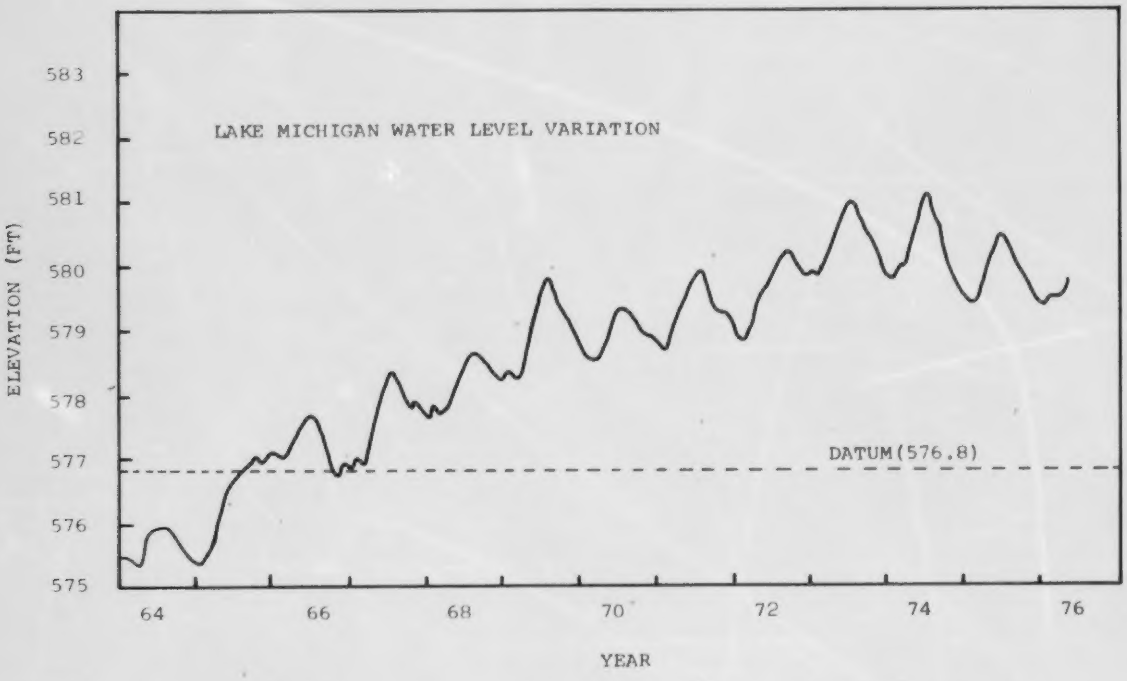

FIGURE 6. Water level variation for Lake Michigan-Huron, from 1964 to 1976 (from Wood, 1976).

Records of lake levels have been maintained since 1860, during which time several periods of extreme water levels were recorded. For example, recent periods of high water levels were experienced in 1951-52, 1971-73 and periods of very low water levels were recorded in the mid 1930's and mid 1960's (Figure 6).

In addition to natural occuring variations in lake levels, man's modification of the Great Lakes drainage system has also affected water levels. These variations, however, are generally insignificant when compared to natural fluctuations. For example, the diversion of the Chicago River from Lake Michigan has a negligible effect upon the levels of the Great Lakes. Grima and Wilson-Hodges (1977) show that the Chicago diversion extracts only enough water to produce a 0.07 m (2.75 in.) fall in Lake Michigan and Huron water levels. In short, man's efforts to control Great Lakes water levels have thus far proven futile.

The net results of lake dynamics and hydrology are experienced in the coastal zone. It is within this narrow band where man encounters the forces of nature and their effects are seen most vividly. During periods of high water levels, the beach is narrow and offers little protection against attack by storm generated waves. In many locations around the Great Lakes, storm waves can strike directly against the base of coastal dunes causing severe erosion and property damage. Periods of extreme low water levels in many ways presents a more formidable danger. It was during the low water period experienced in the mid 1960's that rapid private and commercial development occured in the coastal zone of the Great Lakes. Structures were erected on dunes and bluffs overlooking a seemingly wide and stable beach. Rising water levels of the early 1970's resulted in property value losses around the Great Lakes exceeding hurricane damage on our ocean coasts.

The physical processes outlined in this article are natural occuring processes. As such, their effects must be incorporated into man's plans and activities for the coastal zone. Failure to do so will only result in repetition of the many disasters that have paralleled Great Lakes development. Erosion of shorelines, transport of sediment and the thermal cycle of the lakes are ongoing natural processes which must continue if we are to preserve this largest of fresh water systems.

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Joanne has served as the curriculum coordinator for The Interstate Water Quality Program. In addition to this chapter on Water Treatment and Wastewater Management, she has written the chapter on the Biological Characteristics of Water Pollution, and has edited all of the remaining chapters of your handbook.

She enjoys swimming, bicycling, and cross-country skiing when she is not working and eventually plans to direct an environmental consulting firm.

GLOSSARY

AERATION: the addition of molecular oxygen (O_2) to water via mechanical and/or biological processes.

AEROBIC: life processes that depend on the presence of oxygen.

ANAEROBIC: life processes that can occur without free oxygen.

BENTHIC REGION: the bottom portion of a lake or stream.

BIOCHEMICAL OXYGEN DEMAND (BOD): an approximation of the amount of oxygen used in aerobic, biochemical decomposition.

BIOMASS: the amount of living matter in a particular environment.

CARNIVORES: animal-eaters; secondary consumers that feed on primary consumers.

CHEMICAL OXYGEN DEMAND (COD): the equivalent amount of oxygen that is required to chemically oxidize the constituents of a water sample.

DECOMPOSITION: the breakdown of matter by bacteria, fungi, or other organisms. It changes the chemical make-up and physical appearance of the matter.

EUTROPHIC LAKES: lakes experiencing high inflow of plant nutrients and productivity.

EUTROPHICATION: the process of nourishing, adding of nutrients. A natural aging process of surface waters whereby sedimentation and plant growth can result in the filling in of a lake. Human activities that add nutrients and increase sedimentation can speed up this action.

FOOD CHAIN: life forms linked together through predator-prey relationships. All chains follow a similar pattern: Producers-Herbivores-Carnivores. Decomposers form the link which recycles nutrients.

HAZARDOUS SUBSTANCES: any gas, liquid, or solid that poses a substantial, present or potential threat to life.

HERBIVORES: plant-eaters: primary consumers that feed on the producers.

LIMNETIC ZONE: an open-water area in a lake which extends to the depth of effective light penetration.

LITTORAL ZONE: the shallow-water area within a lake.

MESOTROPHIC LAKES: lakes that have moderate levels of productivity and inflow of nutrients in the continuum of trophic status.

NONPOINT SOURCES: sources of water pollution that cannot be traced to a specific point on the land, e.g., runoff from crop fields, housing developments, or roadways.

NUTRIENTS: elements or compounds essential to growth and development of living things, such as carbon, oxygen, nitrogen, potassium, phosphorus and vitamins.

OLIGOTROPHIC LAKES: lakes with low nutrient levels producing little organic matter; generally deep lakes having saturated oxygen levels.

PHOTOSYNTHESIS: production of carbohydrates and oxygen from carbon dioxide and water in the presence of chlorophyll, using sunlight as an energy source.

PLANKTON: existing free in the water zoo-animal life, phyto-plant life.

POINT SOURCES: a stationary, identifiable location where pollutants are discharged in measurable amounts, e.g., an industrial or municipal waste treatment plant which discharges to a watercourse.

POLLUTANT: a substance added to surface waters that physically, chemically, and/or biologically alters the quality of the water for a particular use.

PRIMARY PRODUCERS: organisms which can grow using inorganic materials; e.g., photosynthetic plants.

PRODUCTIVITY: the rate of growth or production.

PROFUNDAL ZONE: the deep region at the bottom of lakes where lack of light severely limits plant growth.

RESPIRATION: the biochemical breakdown of organic substances with the release of carbon dioxide and the production of ATP molecules.

TROPHOGENIC ZONE: the area in a lake where photosynthesis can occur. It includes the limnetic and littoral zones of a lake.

TROPHOLYTIC ZONE: the area in a lake where light does not penetrate and respiration is the dominant biochemical process. It includes the profundal and benthic zones of a lake.

TURBIDITY: a cloudy condition in water due to suspended solids such as clay, silt or organisms.

WATER QUALITY CRITERION: the concentration of a pollutant that affects a particular use of water.

THE CHEMICAL[1] AND BIOLOGICAL[2] CHARACTERISTICS OF WATER POLLUTION

By

Jim Peterson[1]

JoAnne Westphal[2]

Given a physical framework for the Great Lakes (and specifically Lake Michigan) -- its geological regime, glacial influences and hydrodynamics -- we can now proceed to superimpose chemical and biological characteristics which give each lake system a more unique personality.

A lake system encompasses the entirety of the lake's watershed or drainage basin (surface and subsurface waters), its earthen basin and the air masses which influence its chemistry, biology and hydrodynamics.

Each lake is different. To consider an individual aspect of a lake system may simplify the complex, but the entire system is dependent on each singular characterstic. The lake is like an organism, every function is interrelated in some way.

Like any organism, a lake is what it eats. Its development responds to influences from the whole system. What a lake eats comes largely from its watershed -- for example, a silty watershed will result in a silty lake; a fertile watershed -- a fertile lake; etc.

The principal mechanism for transport of materials into the lake (e.g., the spoon) is the flow of water to the lake. Whatever the spoon can pick up, may be delivered to the lake. A look at the hydrologic cycle displays the sources of materials: air-water interactions (washing of the air mass by rain and snow) and land-water interactions (dissolving, dislodging and distributing earthen materials).

Waters which soak into the ground (infiltrate/percolate) develop a character dependent on the geologic strata to which they have been exposed. For example, biological activity in the soil mantle may deplete the oxygen dissolved in the water; rocks and soil particles may dissolve and contribute calcium, magnesium, carbonates and traces of other elements to the groundwater. The net result is that the dissolved residue content of the water increases as more material dissolves. Any point in the hydrological cycle can accomodate an input of materials to be transported to the lake.

The transformation of materials within a lake is the "digestion" process. Some components are recycled extensively, some deposited eternally, and some moved out hydraulically.

WATER QUALITY

WHAT IS WATER QUALITY AND HOW DO WE DEFINE GOOD OR POOR WATER QUALITY? WATER QUALITY IS THE COMBINATION OF THE PHYSICAL, CHEMICAL AND BIOLOGICAL CHARACTERISTICS OF WATER WHICH AFFECTS ITS USE FOR SOME SPECIFIC PURPOSE. WHAT IS "GOOD" WATER QUALITY DEPENDS ON YOUR WATER QUALITY CRITERIA -- YOUR PERCEPTION OF ACCEPTABLE WATER CHARACTERISTICS. A SWIMMER, AN ESTHETE, AN IRRIGATOR, A WATER SUPPLY SPECIALIST, OR A WASTE DISPOSER HAVE DIFFERENT, AND NOT NECESSARILY COMPATIBLE, NOTIONS OF THE ACCEPTABLE CHARACTERISTICS OF WATER FOR THEIR USE. SOME OF THE IMPORTANT WATER CHARACTERISTICS TO THESE INDIVIDUALS MAY INCLUDE CLARITY OF THE WATER, ABUNDANCE AND KINDS OF PLANTS AND ANIMALS, TOXICITY TO SPECIFIC ORGANISMS, ODORS, COLOR, TEMPERATURE, DEPTH OR TASTE.

THESE FACTORS ARE ALL INTERDEPENDENT AND MAY REPRESENT ONLY A SYMPTOM OF "POOR" WATER QUALITY WITHOUT INDICATING THE CAUSE HOWEVER, WE NEED TO KNOW A CAUSE TO UNDERSTAND A SYMPTOM BEFORE A FUNDAMENTAL SOLUTION CAN BE DEVELOPED.

WATER THAT DOES NOT MEET OUR STANDARDS FOR "GOOD" QUALITY MAY BE TERMED POLLUTED. IT IS APPARENT THEN THAT POLLUTION IS AS NON-DESCRIPT AS WATER QUALITY. POLLUTION RESULTS IN SOME UNDESIRABLE CHANGE IN THE PHYSICAL, CHEMICAL AND/OR BIOLOGICAL CHARACTERISTICS OF THE WATER WHICH CHANGES ITS DESIRABILITY FOR SOME SPECIFIC USE. A POND IS "ENRICHED" WITH MANURE TO INCREASE FISH PRODUCTION, BUT A LAKE IS "POLLUTED" WITH MANURE WHEN BLUE-GREEN ALGAE BEGIN TO FLOAT AND CAUSE UNDESIRABLE ODORS. AGAIN, POLLUTION IS A QUESTION OF AN INDIVIDUAL'S PERSPECTIVE.

SOURCES OF WATER POLLUTION:

WHAT ARE THE SOURCES OF POLLUTION? CONSIDER FIRST THE FACTORS AND PROCESSES WHICH CHANGE PURE, DISTILLED-BY-NATURE WATER INTO A HIGHLY PRODUCTIVE SOUP THAT CAN FILL A LAKE BASIN.

EVAPORATION, A PURIFICATION PROCESS ONLY MOTHER NATURE CAN AFFORD ON SUCH A GRAND SCALE, EFFECTIVELY "DISTILLS" WATER FROM EVEN THE FOULEST OF MATRICES. UPON CONDENSATION, GAS TRANSFER REACTIONS SUPPLY NITROGEN, OXYGEN, CARBON DIOXIDE AND OTHER GASES TO THE DROPLETS. MOVEMENT WITHIN THE ATMOSPHERE PROMOTES CAPTURE OF AEROSOL AND MIST PARTICLES -- COMPOSITION INDESCRIPT. SOME OF THE SOURCES INCLUDE DUST FROM AGRICULTURE; SULFUR AND NITROGEN OXIDES FROM VOLCANOES AND INDUSTRY; URBAN AEROSOLS AND MISTS; AND VOLATILE ORGANIC COMPONENTS FROM FORESTS, ETC.

BY THE TIME PRECIPITATION REACHES THE EARTH'S SURFACE, THE EXPRESSION "PURE AS THE DRIVEN SNOW" LEAVES PLENTY OF ROOM FOR COMPROMISE. THE FAMILIAR WARM SUMMER RAINS DEPOSIT SUSPENDED AND DISSOLVED DUST OVER A WATERSHED. IN SOME PLACES THERE IS ENOUGH NITROGEN AND PHOSPHORUS COMPOUNDS IN THE RAIN AND SNOWFALL TO KEEP A

LAKE WELL NOURISHED (EUTROPHIC) FROM PRECIPITATION ALONE.

EVEN WITHOUT THE PRESENCE OF CONCENTRATED ACTIVITIES (INDUSTRIAL, URBAN, AGRICULTURAL), WATER CLEANSES THE EARTH'S SURFACE AS IT RUNS OFF THE LAND BY DISLODGING ORGANIC DEBRIS, CLAY, SILT AND SAND-SIZED PARTICLES, AND BY DISSOLVING MATERIALS AS IT GOES. THE MORE ENERGY THAT THE FLOW OF WATER (THE SPOON) HAS, THE MORE MATERIAL IT CAN MOVE. LONG STEEP SLOPES, INTENSE RAINFALL, BARE SOIL, FURROWS THAT RUN UP AND DOWN HILLS, AND SOILS WHICH WILL NOT SOAK UP WATER QUICKLY ALL CONTRIBUTE TO HIGH ENERGY FLOWS CAPABLE OF MOVING MORE AND LARGER PARTICLES.

THE SOURCES OF MATERIALS JUST REVIEWED DO NOT ORIGINATE IN ONE SPECIFIC LOCATION AND ARE NOT DELIVERED TO THE WATER COURSE AT A SPECIFIC POINT. FOR REGULATORY PURPOSES, THESE ARE "NON-POINT-SOURCE" MATERIALS OR POLLUTANTS; THESE MATERIALS ARE GENERATED OVER BROAD AREAS FROM DIVERSE, NON-SPECIFIC SOURCES AND ARE DELIVERED BY NATURAL PROCESSES. EXAMPLES OF NON-POINT SOURCES INCLUDE 1) SNOWMELT AND STORMWATER RUNOFF FROM STREETS AND HIGHWAYS CARRYING CORROSION AND ABRASION PRODUCTS FROM VEHICLES, PLANT LITTER, GARBAGE, GREASE, OIL, GRIT AND CHEMICALS; 2) RUNOFF FROM TILLED LANDS AND CONSTRUCTION AND MINING SITES CARRYING SOIL PARTICLES, FERTILIZERS, HERBICIDES, PLUS PLANT AND ANIMAL DETRITUS; 3) RUNOFF FROM FORESTED LANDS CARRYING PLANT LITTER, DISSOLVED PLANT AND SOIL MATERIALS; AND 4) WATER (LEACHATE) FROM LANDFILLS AND OTHER WASTE DISPOSAL AREAS CARRYING SEDIMENT, TOXIC MINERAL AND ORGANIC COMPOUNDS, PLANT NUTRIENTS AND DISEASE ORGANISMS. WITH NON-POINT POLLUTION, THE NATURE AND EXTENT OF CONTAMINANTS IS VERY DIVERSE AND CAN VARY SEASONALLY AS WELL AS SPATIALLY.

POLLUTANTS

THE NEXT STEP IS TO CONSIDER THE KINDS OF MATERIAL (POLLUTANTS) ADDED TO THE WATER AND THEIR EFFECTS ON THE PHYSICAL AND BIOLOGICAL CHARACTERISTICS OF THAT BODY OF WATER. THERE ARE SEVERAL CLASSES OF POLLUTANTS AND EACH POLLUTANT CAN HAVE AN INDIVIDUAL EFFECT ON A RECEIVING BODY OF WATER AS WELL AS PRODUCE AN OVERALL EFFECT WHICH RESULTS FROM VARIOUS COMBINATIONS OF POLLUTANTS IN WATER.

PARTICULATES

SOLID PARTICLES ARE THE EASIEST TO SEE AND ARE USUALLY THE MAJOR CONTAMINANT IN WATER ON A WEIGHT OR VOLUME BASIS. SIZE FRACTIONS RUN FROM TRASH AND DEBRIS TO MICROSCOPIC, COLLOIDAL CLAYS AND BACTERIA. THE ANALYSIS FOR SUSPENDED RESIDUE (ALSO KNOWN AS PARTICULATES, TOTAL SUSPENDED SOLIDS, SEDIMENT AND NONFILTERABLE RESIDUE) INVOLVES SEPARATION OF THE SUSPENDED MATERIAL FROM A KNOWN VOLUME (OR WEIGHT) OF WATER, DRYING THE MATERIAL, AND WEIGHING THE RESIDUAL. RESULTS ARE

REPORTED ON A WEIGHT PER VOLUME BASIS, SUCH AS MILLIGRAMS OF RESIDUE PER LITER (MG/L) OR UNIT WEIGHT OF RESIDUE PER MILLION UNIT WEIGHTS OF SAMPLE (PARTS PER MILLION, PPM). A FURTHER ANALYTICAL PROCESSING -- SLOW ASHING (BURNING) OF THE SAMPLE -- ROUGHLY SEPARATES THE MINERAL COMPONENTS (FIXED RESIDUE) FROM THE ORGANIC DEBRIS CONTENT (VOLATILE RESIDUE).

PARTICULATE SOURCES:

NATURAL PROCESSES PRODUCE SUSPENDED PARTICLES IN WATERS BY: WATER AND WIND EROSION OF SOILS AND DEBRIS; RESUSPENSION OF LAKE AND STREAM SEDIMENTS; GROWTH OF PLANKTONIC (FREE FLOATING) PLANTS AND ANIMALS; AND CHEMICAL COMBINATIONS IN WATER FORMING SOLID COMPONENTS SUCH AS CALCIUM CARBONATE (MARL OR LIME). LAND ACTIVITIES SUCH AS MINING, LOGGING, TILLING, BUILDING AND ROAD CONSTRUCTION, CHANNELIZING, DREDGING AND GRAZING, ALL CONTRIBUTE TO MORE RAPID TRANSPORT -- PARTICULARLY OF SOIL PARTICLES. ADD IN INDUSTRIAL, COMMERCIAL AND MUNICIPAL EXPANSION, AND THE FULL GAMUT OF CULTURAL ACTIVITIES, INCLUDING "MANAGEMENT" OF WATER LEVELS, AND THE SUSPENDED MATERIAL LOAD DELIVERED TO LAKE MICHIGAN BECOMES A SERIOUS PROBLEM.

EFFECTS OF PARTICULATES:

THE SMALLER PARTICLES SUSPENDED IN WATER IMPART A CLOUDINESS TO WATER CALLED "TURBIDITY". WATER LOOKS CLOUDY BECAUSE LIGHT IS SCATTERED BY THE PARTICLES AS IT PASSES INTO THE WATER. FOR DRINKING WATER USE, TURBIDITY HAS ADVERSE EFFECTS FROM A PSYCHOLOGICAL AS WELL AS PHYSICAL STANDPOINT. TURBID WATER "DOES NOT LOOK RIGHT"; THEREFORE, RECIPIENTS MAY OPT FOR A LESS SAFE, "CLEAR" WATER SUPPLY RATHER THAN ONE THAT LOOKS CLOUDY OR "UNCLEAN". TURBID WATER REQUIRES MORE CHEMICALS FOR ADEQUATE TREATMENT, AND IT IS MORE DIFFICULT TO DISINFECT. INDUSTRIAL USE FOR FOOD PROCESSING, COOLING, BEVERAGES, BOILER FEEDWATER, PAPER MAKING AND OTHERS IS ADVERSELY AFFECTED BY EVEN LOW LEVELS OF TURBIDITY. SUSPENDED PARTICLES, BY VIRTUE OF THEIR SURFACE AREA MAY ABSORB OILS, ORGANIC COMPOUNDS AND TOXIC METALS AND FACILITATE DEPOSITION OF THESE COMPONENTS AS THEY SETTLE IN A WATER BODY. THE EFFECTS OF TURBIDITY ON THE LIVING PORTIONS OF LAKE SYSTEMS CAN BE DRAMATIC. MOST IMPORTANTLY SUSPECTED SOLIDS INDIRECTLY AFFECT O_2 AND PRODUCTIVITY LEVELS BY REDUCING PHOTOSYNTHESIS. THIS IN TURN AFFECTS ENERGY TRANSFORMATIONS AND THE DISTRIBUTION OF PLANTS AND ANIMALS IN A LAKE. FURTHERMORE, TURBIDITY WILL PHYSICALLY CLOG THE GILLS OF FISH AND SHELLFISH; CHANGE WATER DEPTH DUE TO FINAL DEPOSITION OF SUSPENDED MATERIALS; AND AFFECT THE AVAILABILITY OF TOXIC SUBSTANCES AND PLANT NUTRIENTS CARRIED IN WITH THE SOLID PARTICLES.

QUALITY CRITERIA:

FOR DRINKING WATER AN UPPER LIMIT OF 1 TO 5 UNITS HAS BEEN SPECIFIED. FOR

PROTECTION OF FISH AND AQUATIC LIFE, UPPER LIMITS OF "NONE ABOVE NATURAL LEVELS" TO 25 MG/L OF SUSPENDED SOLIDS HAVE BEEN SPECIFIED.

NUTRIENTS

ANOTHER CLASS OF POLLUTANTS IS PLANT NUTRIENTS. THE POLLUTIONAL ASPECTS ARE CONCERNED WITH THE SECONDARY EFFECT OF THE NUTRIENTS -- I.E., EUTROPHICATION. EUTROPHICATION IS GENERALLY ASSOCIATED WITH THE OVER-ABUNDANT PRODUCTION OF PLANTS WHICH MAY RESULT IN TURBIDITY, OXYGEN DEPLETION, UNDESIRABLE TASTES AND ODORS, TOXINS, AND INTERFERENCES WITH NAVIGATION.

LAKE SYSTEMS AND OTHER SURFACE WATERS ARE FREQUENTLY CLASSIFIED ON THE BASIS OF THEIR NUTRIENT LEVELS. IN GENERAL, LAKES HAVING RELATIVELY SMALL AMOUNTS OF NUTRIENTS AND LOW LEVELS OF PRODUCTIVITY ARE CALLED OLIGOTROPHIC LAKES. BODIES OF WATER HAVING HIGH PRODUCTIVITY (I.E., PRODUCING A LOT OF BIOMASS) AND EXPERIENCING HIGH FLUXES OF AQUATIC PLANT NUTRIENTS ARE CALLED EUTROPHIC LAKES/STREAMS. MESOTROPHIC WATERS ARE OF AN INTERMEDIATE TROPHIC STATUS.

THE NUTRIENT SUPPLY IN AND OF ITSELF DOES LITTLE HARM. IT IS THE INFLUENCE ON BIOLOGICAL PRODUCTIVITY WHICH IS IMPORTANT. GIVEN THE NECESSARY NUTRIENTS, SUNLIGHT AND SUITABLE HABITAT AND TEMPERATURE, SPECIFIC PLANTS WILL FLOURISH. THESE PLANTS, USUALLY BLUE-GREEN ALGAE AND GREEN ALGAE, PROVIDE THE INITIAL LINK IN THE ENTIRE FOOD CHAIN OF AQUATIC SYSTEMS. THIS LINK IS THE PRIMARY PRODUCTIVITY IN LAKES. THE RATES OF PRIMARY PRODUCTIVITY IN LAKES CONTROLS THE ENTIRE ENERGY TRANSPORT SYSTEM (BY AFFECTING AVAILABLE OXYGEN MOLECULES) WHICH DIRECTLY AFFECTS THE CHEMICAL QUALITY OF WATER. IN GENERAL, A LAKE SYSTEM HAVING A SPARSE NUTRIENT SUPPLY (OLIGOTROPHIC) WILL SUPPORT A SPARSE TOTAL WEIGHT OF PLANTS AND ANIMALS (BIOMASS). INCREASING THE SUPPLY OF WHICHEVER NUTRIENT WAS LIMITING THE PRODUCTION OF MORE BIOMASS WILL PRODUCE AN INCREASE IN THE PLANTS PRODUCTIVITY (PRIMARY PRODUCTIVITY). THE PLANTS ARE AN ENERGY SOURCE (FOOD) FOR SECONDARY PRODUCERS (HERBIVORES) WHOSE TOTAL MASS WILL RESPOND TO AN INCREASED FOOD SUPPLY. CARNIVORES RESPOND SIMILARLY. THE ENTIRE SYSTEM CAN BE LIMITED BY THE AVAILABILITY OF A SINGLE NUTRIENT REQUIRED FOR GROWTH BY THE PRIMARY PRODUCER. THIS IS CALLED THE LIMITING NUTRIENT CONCEPT.

THE EUTROPHICATION OF LAKES IS A NATURAL PROCESS WHICH IS DEPENDENT UPON THE TRANSPORT OF SUSPENDED AND DISSOLVED NUTRIENTS FROM A LAKE'S DRAINAGE BASIN. THE NATURAL RATE MAY BE IMMEASURABLY SLOW. CULTURAL ACTIVITIES HAVE SPEEDED THE TRANSPORT OF THESE MATERIALS FOR A MYRIAD OF LAKES DURING THE LAST CENTURY, BOTH INTENTIONALLY AND BY DEFAULT. AS A RESULT OF THIS RAPID ENRICHMENT, (FORCE FEEDING),

60

Numerous lakes are experiencing changes in their physical and biological composition. These changes are exhibited in increased frequencies of algal blooms and in differences in species composition of algae (i.e., from green to blue-green species). Rooted aquatic plants, too, have become nuisances as a result of over-abundance. Dissolved osygen super-saturation and depletion; increased fish biomass; changes in fish species composition; putrid odors, and fish kills are other indications of lake change. Table 1 summarizes major differences between oligotrophic and eutrophic lakes.

We have begun to consider the response of lakes to enrichment by plant nutrients in general. A further refinement would consider each nutrient separately as to its sources, biogeochemical cycles, and perhaps most importantly, the potential for control of a specific nutrient or nutrients to achieve a reversal of the symptoms of eutrophication of lakes. Based on what is known about plant nutrition, plant composition, and availability or supply of nutrients to lakes, compounds of nitrogen (N), phosphorus (P), and carbon (C) need to be considered.

Algae contain about 1 unit of P, 7

PARAMETER	Oligotrophic	Eutrophic
Aquatic plant production	Low	High
Aquatic animal production	Low	High
Aquatic plant nutrient flux	Low	High
Oxygen in the hypolimnion	Present	Absent
Depth	Tend to be deeper	Tend to be shallower
Water quality for most domestic and industrial uses	Good	Poor
Total salts or conductance	Usually lower	Sometimes higher
Number of plant and animal species	Many	Fewer

TABLE 1 Major differences between oligotrophic and eutrohpic lakes (Lee, 1970)

units of N, and 40 units of C to 100 unit weights of dry material. That is, 100 pounds (grams) of dried algal plant material would contain about 40 pounds (grams) of carbon, 7 pounds (grams) of nitrogen and 1 pound (gram) of phosphorus (the other 52 weight units are hydrogen, oxygen, and other trace elements, combined with the C, N and P). This means that given the proper habitat, adequate sunlight, a suitable temperature and sufficient other chemical necessities, the addition of one pound of phosphorus (in a biologically available form) could result in growth of 100 pounds (dryweight) of algae, or about 500 pounds of wet, live algae. Similarly, if available nitrogen compounds were limiting production, a 7 pound addition would result in 500 pounds live weight (a 71 fold increase). With a few exceptions*, nitrogen or phosphorus are the two nutrients limiting algal production in lake systems.

Eutrophication control strategies have focused on phosphorus for several reasons:

1) it may be the limiting nutrient for nuisance aquatic plant growth; 2) its chemical characteristics make it amenable to control (i.e., there is no significant gaseous phase and sorption and precipitation reactions readily remove some forms); and 3) significant quantities are introduced to the system through cultural activities which may be controlled (Table 2).

Phosphorus concentrations are reported as weights of phosphorus per sample volume -- milligrams phosphorus per liter or micrograms of phosphorus per liter (µg/l). Researchers have reported (Sawyer, 1965; Vollenweider, 1968) that as little as 0.010 mg/l P in water can support excessive crops of algae and other aquatic plants.

The "availability" of phosphorous in aquatic ecosystems is dependent on the chemical form of the phosphorus. In general, orthophosphate ($PO_4^{\equiv}$) is the form of phosphorus most readily absorbed by plants although organic P may contribute to biological growth also. Phosphorus forms change rapidly in environmental systems so researchers usually conduct at least 3 water analyses: total phosphorus, orthophosphate, and organic P; this gives researchers an idea of the upper limits of availability (total P) as well as existing available concentrations (PO_4 and organic P). After phosphorus, nitrogen is generally considered the second most likely limiting nutrient in aquatic systems. Concentrations of 0.3 mg/l N (in the form of ammonia and nitrate) is usually considered the concentration level needed

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*Diatom growth may be limited by availability of silicon, and in some instances, iron may limit plant growth.

SEASON:	SPRING	SUMMER	FALL	WINTER
TOTAL LOADING (LBS.):	2,840,000	1,760,000	1,360,000	1,230,000
SOURCE CONTRIBUTIONS (%):				
RURAL RUNOFF	39	2	4	15
MUNICIPAL TREATMENT PLANTS	25	44	39	35
URBAN RUNOFF	1	2	2	2
LAKE WINNEBAGO	28	40	39	30
INDUSTRIAL	7	12	16	18

TABLE 2

CONTRIBUTIONS OF PHOSPHORUS (TOTAL P) TO LOWER GREEN BAY, LAKE MICHIGAN, FROM MAJOR SOURCES IN THE LOWER FOX RIVER DRAINAGE BASIN. LOADING FIGURES ARE IN POUNDS (TO CONVERT TO KG, MULTIPLY BY 0.454). LAKE WINNEBAGO IS A LARGE, SHALLOW, ENTROPHIC LAKE THAT RECEIVES SURFACE RUNOFF FROM THE MAIN AREA OF THE FOX-WOLF RIVER DRAINAGE BASIN, AND SERVES AS THE INTERMEDIATE SOURCE OF THE LOWER FOX RIVER. THE FOX-WOLF DRAINAGE BASIN IS THE LARGEST IN THE LAKE MICHIGAN WATERSHED WITH AN AREA OF 6,443 SQUARE MILES (16,187 KM^2). (AFTER SAGER AND WIERSMA, 1975)

TO PRODUCE EXCESSIVE PLANT GROWTH IN AQUATIC SYSTEMS. "AVAILABILITY" OF NITROGEN FOR PLANT UPTAKE APPEARS TO BE MUCH LESS IMPORTANT FOR NITROGEN THAN FOR PHOSPHORUS. SOME AQUATIC PLANTS CAN USE EITHER NITRATE (NO_3^-) OR AMMONIUM (NH_4^+) AS WELL AS DISSOLVED N_2 GAS.

BECAUSE MOST NITROGEN SPECIES ARE SOLUBLE IN WATER AND RESIST SORPTION (STICKING) TO SOIL PARTICLES, NITROGEN COMPOUNDS READILY PASS THROUGH SOIL PROFILES INTO THE GROUNDWATER, MAKING NITROGEN MUCH MORE DIFFICULT TO CONTROL THAN PHOSPHORUS SPECIES. ATMOSPHERIC LOADING OF HIGH CONCENTRATIONS OF NITROGEN OXIDES OVER INDUSTRIAL AREAS HAS ALSO CONTRIBUTED SIGNIFICANT QUANTITIES OF NITROGEN TO LAKE SYSTEMS VIA "ACID RAINS". FURTHERMORE, THE ABILITY OF CERTAIN PLANT SPECIES TO "FIX" NITROGEN -- THAT IS CONVERT IT FROM A GAS TO AN ORGANIC FORM -- MAKES CONTROL OF THIS CONTRIBUTOR TO EUTROPHICATION ALMOST IMPOSSIBLE.

SOME INDIVIDUALS FEEL THAT CARBON SHOULD BE LISTED AS ONE OF THE CRITICAL ELEMENTS IN TERMS OF EUTROHPICATION. EVIDENCE, TO DATE HOWEVER, SUGGESTS THAT CARBON (IN THE FORM OF CO_2) IS ONLY LIMITING IN THE PRESENCE OF EXCESSIVE ALGAE BLOOMS WHEN EUTROPHICATION HAS ALREADY REACHED EXCESSIVE LIMITS. AT THAT POINT, WATER QUALITY HAS ALREADY DETERIORATED TO SUCH A DEGREE THAT FURTHER PLANT PRODUCTION IS INSIGNIFICANT (LEE, 1970).

OXYGEN DEMANDING WASTES

ANY SUBSTANCE THAT ENTERS AN AQUATIC SYSTEM AND ULTIMATELY REQUIRES OXYGEN FOR EITHER ITS CHEMICAL AND/OR BIOLOGICAL DECOMPOSITION IS CALLED AN OXYGEN-DEMANDING WASTE (O.D.W.). ODW'S MAY BE BIOLOGICAL IN NATURE -- E.G., DEAD PLANT AND ANIMAL TISSUES LIKE LEAF LITTER, LAWN CLIPPINGS, GARBAGE DISPOSAL WASTES, REPRODUCING PLANT AND ANIMAL TISSUES THAT WILL EVENTUALLY DIE, FECAL MATTER, ETC. -- OR THEY BE CHEMICAL IN NATURE -- E.G., LOW OXIDATION-STATE COMPOUNDS LIKE HYDROGEN SULFIDE, MERCAPTANS, ETC. IN EITHER CASE, THESE MATERIALS WHEN THEY BEGIN TO DECOMPOSE (OR UNDERGO OXIDATION) CREATE AN OXYGEN DEMAND ON A STREAM OR LAKE THAT MAY OR MAY NOT BE MET BY NATURAL PROCESSES INVOLVING OXYGEN REPLENISHMENT. IF TOO GREAT OF A DEMAND FOR OXYGEN IS CREATED, AS COMPARED TO SUPPLY, THEN THE BIOLOGICAL ORGANISMS OF A BODY OF WATER WILL BEGIN TO UNDERGO PHYSIOLOGICAL STRESS CONDITIONS CAUSED BY ENERGY DEFICIENCIES AND ANOXIA.

BIOCHEMICAL PROCESSES AFFECTING OXYGEN LEVELS IN WATER:

ALL LIVING ORGANISMS, WHETHER TERRESTIAL OR AQUATIC, DEPEND ON CHEMICAL TRANSFORMATIONS IN THEIR ENVIRONMENT TO CARRY ON LIFE FUNCTIONS. CHEMICAL TRANSFORMATIONS PROVIDE THE "LIFE-BLOOD" OF LIVING ORGANISMS BECAUSE THEY PRODUCE ENERGY, AND THIS ENERGY IS USUALLY STORED IN THE FORM OF CHEMICAL BONDS. THE ACTUAL AMOUNT OF ENERGY STORED DEPENDS ON THE MOLECULE UNDER STUDY AND THE CHEMICAL PROCESSES UNDER WHICH IT WAS FORMED. ORGANIC MOLECULES (E.G., FATS, PROTEINS, AND CARBOHYDRATES) GENERALLY STORE A GREATER AMOUNT OF ENERGY THAN INORGANIC MOLECULES (E.G., CARBON DIOXIDE, WATER, AMMONIA, ETC.). THE ENERGY THAT IS OBTAINED FROM VARIOUS CHEMICAL BONDS PROVIDES THE "FUEL" BY WHICH AN ORGANISM CAN WORK, GROW, REPAIR TISSUES, AND REPRODUCE. WITHOUT ENERGY, AND THE INFINITE NUMBER OF CHEMICAL COMPOUNDS THAT HOUSE, TRANSFER, AND TRANSFORM IT, LIFE PROCESSES WOULD CEASE, AND LIFE, AS WE KNOW IT ON EARTH, COULD NOT EXIST.

THE SUN IS THE ULTIMATE SOURCE OF ENERGY FOR THE EARTH. GREEN PLANTS, THROUGH A COMPLEX CHEMICAL PROCESS KNOWN AS PHOTOSYNTHESIS, ABSORB SUNLIGHT AND TRANSFER ITS ENERGY VIA THE CHEMICAL RECOMBINATION OF CARBON DIOXIDE (CO_2) AND WATER (H_2O) TO A SUGAR CALLED GLUCOSE ($C_6H_{12}O_6$) (FIG. 1).

$$\boxed{12\ H_2O + 6\ CO_2 + \text{ENERGY FROM SUN} + \text{CHLOROPHYLL IN PLANTS} \rightarrow C_6H_{12}O_6 + 6\ H_2O + 6\ O_2}$$

FIGURE 1. THE GENERAL CHEMICAL REACTION OF PHOTOSYNTHESIS IN GREEN PLANTS.

GLUCOSE IS A HIGH ENERGY, ORGANIC COMPOUND THAT IS USED TO FORM OTHER HIGH ENERGY, ORGANIC MOLECULES USED FOR FOOD storage and/or structural purposes, i.e., fats, proteins, and carbohydrates. This conversion of glucose into fat, protein, and carbohydrate occurs in both the plants that photosynthesis and the animals that ingest the plant material. The energy that was originally provided by the sun in the formation of glucose still remains in the chemical bonds of these new storage and structural compounds. When there is a call for energy by the organism, a reverse set of transformations occur until glucose is again present; this glucose is then used for the production of ATP (adenine triphosphate) which is the energy transfer molecule used by plants and animals to perform their life functions.

The breakdown of glucose to produce ATP molecules is called respiration. Respiration occurs in both plants and animals. The most energy-efficient form of respiration occurs in the presence of oxygen and is known as aerobic respiration (Fig. 2).

$$6\ H_2O + C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 12\ H_2O + 36\ ATP$$

Figure 2. The general chemical reaction for aerobic respiration.

Aerobic organisms need oxygen because it can accept or donate electrons which are involved in energy transfer steps within organisms; this transfer of electrons results in the availability of energy in the form of ATP that organisms can use to maintain life processes. Without free oxygen, organisms could utilize only a fraction of the energy that is bound in chemical bonds that comprise food molecules. Occasionally, aerobic organisms can use nitrogen or sulfur compounds rather than oxygen as an electron conveyor, but the energy produced is too low to allow continued life processes, and if the organisms cannot obtain a fresh supply of free oxygen in a relatively short period of time, they will die of anoxia. The end products of aerobic decomposition of organic matter are carbon dioxide (CO_2), water, ATP molecules and high oxidation states of nitrogen (i.e., nitrate), sulfur (sulfate) and other trace elements. It is interesting to note, that aerobic respiration is almost the exact reverse process of photosynthesis -- the exception being that the energy that was originally in the form of sunlight has been converted to the chemical bonds of ATP.

Respiration that occurs in the absence of oxygen -- i.e., anaerobic respiration -- does not produce the same amount of energy or the same end products as aerobic respiration (Fig. 3). This is because the end products of anaerobic respiration -- that is ethanol (in the case of plants) and lactic acid (in the case of animals) still have a lot of energy stored in their chemical bonds. Only if free oxygen (O_2) is present, can the energy stored in the bonds of these two chemicals be transferred to the bonds of the ATP molecules. In aquatic systems where anaerobic decomposition is taking place (usually the bottom sediments), the production of low oxidation state sulfur compounds (mercaptans, sulfides), nitrogen compounds (ammonia, amines), and other forms of trace elements can produce foul smells and materials that are toxic to many forms of aquatic life.

Glucose ($C_6H_{12}O_6$)	
2 Lactic Acid	2 CO_2 +
+	2 Ethanol
2 ATP	+ 2 ATP
In animals and some microorganisms	In most plants & many microorganisms

Figure 3. The general chemical reaction for anaerobic respiration.

Biophysical Processes Affecting Oxygen Levels in Water:

We have only briefly touched on the importance of oxygen for energy production in aquatic systems. Surprisingly however, it is this role of oxygen in energy transformations that is at the basis of most chemical and biological considerations when discussing water pollution. Let us expand on the role of oxygen in aquatic systems and attempt to understand what impact the presence (or absence) of oxygen has on aquatic ecosystems and what impacts various water "pollutants" can have on aquatic oxygen concentrations.

There are two principal sources of dissolved oxygen in water: 1) aeration; and 2) photosynthesis. The first source depends solely on physical processes in the environment; the second source relies on biological activities in an appropriate physical and chemical environment.

Aeration:

While air contains about 21% oxygen, water saturated with air will contain only 0.0005% to 0.0015% molecular oxygen by weight. The solubility of oxygen (and other gases) in water is influenced by the water's temperature, the pressure of oxygen in the gas in contact with the water (i.e., the atmospheric pressure) and to some extent by the amount of other dissolved material in the water (salinity or dissolved residues). In general, the concentration of dissolved oxygen decreases in water as the water becomes warmer and increases as the atmospheric pressure becomes greater as shown in Table 3.

Solubility decreases slightly as salinity increases. For example, the solubility of oxygen in water exposed to water-saturated air at 10°C and 760 mm H_2O pressure is 11.3 mg/l (Table 3). For water with a higher salinity or ionic strength (from more dissolved material),

TEMPERATURE °C	(°F)	PRESSURE MM (INCHES) HG 725 (28.54)	750 (29.53)	760 (29.92)	775 (30.5)
0	32	13.9	14.4	14.6	14.9
5	41	12.2	12.6	12.8	13.1
10	50	10.8	11.2	11.3	11.6
15	59	9.7	10.0	10.2	10.4
20	68	8.7	9.1	9.2	9.3
25	77	8.0	8.3	8.4	8.5
30	86	7.3	7.6	7.7	7.8
35	95	6.7	7.0	7.1	7.2

*IN CONTACT WITH WATER-SATURATED AIR

TABLE 3. SOLUBILITY OF OXYGEN (MG/L) IN WATER AT VARIOUS TEMPERATURES AND ATMOSPHERIC PRESSURES*

THE SOLUBILITY DECREASES TO 10.7 MG/L WHEN THE CHLORIDE CONCENTRATION IS 5,000 MG/L AND TO 10.1 MG/L AT 10,000 MG CL/L, OR ABOUT 0.012 MG/L PER 100 MG CL/L INCREASE.

ALTHOUGH THE SATURATION LEVEL (SOLUBILITY) OF OXYGEN CAN BE DESCRIBED FOR A CERTAIN TEMPERATURE, PRESSURE AND SALINITY, PROCESSES WHICH CONTROL THE RATE OF OXYGEN TRANSFER FROM THE AIR TO WATER ARE MORE COMPLICATED. THE CONDITION OF THE AIR-WATER INTERFACE AND HOW FAR THE WATER IS FROM BEING SATURATED WITH OXYGEN ARE THE KEY FACTORS. RAPID TRANSFER OF OXYGEN ACROSS THE INTERFACE RELIES UPON 1) THE EXPOSURE OF A LARGE WATER SURFACE AREA TO THE ATMOSPHERE; AND 2) A LARGE OXYGEN DEFICIT (I.E., A BIG DIFFERENCE BETWEEN THE ACTUAL OXYGEN CONCENTRATION IN THE WATER AND ITS POSSIBLE SATURATION CONCENTRATION). TRANSFER OF OXYGEN INTO WATER OCCURS AT GREATER RATES WHEN TURBULENCE IS A PART OF THE AIR AND WATER INTERFACE. THIS TURBULENCE ALLOWS MORE WATER TO COME IN CONTACT WITH THE OXYGEN THAT IS IN THE ATMOSPHERE. THE OXYGEN DIFFERENCE BETWEEN THE TWO MASSES (I.E., WATER AND AIR) WILL DETERMINE THE ACTUAL AMOUNT AND RATE OF OXYGEN TRANSFER. IN GENERAL, THE GREATER THE TURBULENCE AND SURFACE AREA EXPOSED TO THE ATMOSPHERE, THE HIGHER THE RATE OF O_2 TRANSFER TO THE WATER BODY.

PHOTOSYNTHESIS:

PHOTOSYNTHESIS IS THE SECOND WAY THAT FREE OXYGEN CAN GET INTO AQUATIC ECOSYSTEMS. AS MENTIONED BEFORE, PHOTOSYNTHESIS IS A BIOCHEMICAL PROCESS WHEREBY GREEN PLANTS USE LIGHT ENERGY TO CONVERT CHEMICAL NUTRIENTS LIKE WATER, CARBON DIOXIDE, NITROGEN, PHOSPHORUS, ETC., INTO PLANT FATS, SUGARS, AND PROTEINS THAT ARE USUALLY STORED AS NEW PLANT AND ANIMAL CELLS. THE PROCESS RELEASES OXYGEN AS A BY-PRODUCT.

PHOTOSYSTHESIS DEPENDS ON THREE FACTORS FOR THE PROCESS TO OCCUR: 1) A POPULATION OF GREEN PLANTS: 2) AN ADEQUATE SUPPLY OF SUNLIGHT; AND 3) AVAILABLE INORGANIC NUTRIENTS IN SUITABLE FORMS AND

CONCENTRATIONS. OBVIOUSLY, ALL THREE FACTORS MUST BE IN THE SAME PLACE AT THE SAME TIME FOR THE PROCESS TO OCCUR.

IF ONE WERE TO DIAGRAMMATICALLY DEPICT A TYPICAL LAKE SYSTEM, IT WOULD BE DIVIDED INTO ZONES (FIG. 4) BASED ON THE PRESENCE OR ABSENCE OF SUNLIGHT AND THEREFORE, THE OCCURRENCE OF PHOTOSYNTHESIS. SINCE THE ENERGY SOURCE OF A LAKE IS SUNLIGHT, THE DEPTH TO WHICH LIGHT CAN PENETRATE AND PLANTS CAN PHOTOSYNTHESIZE IS CALLED THE TROPHOGENIC ZONE. THIS ZONE ROUGHLY CORRESPONDS TO THE EPILIMNION, AND IT IS THE PART OF THE LAKE WHERE ROOTED OR FREE FLOATING PLANTS (LIKE ALGAE) CAN ACTIVELY PHOTOSYNTHESIZE. AS A RESULT OF THIS PHOTOSYNTHETIC ACTIVITY AND THE NATURAL AERATION THAT IS OCCURRING AT THE AIR-WATER INTERVACE DUE TO WIND AND WAVE ACTION, WATERS IN THE EPILIMNION TEND TO HAVE RELATIVELY HIGH OXYGEN CONCENTRATIONS AND MAY, AT TIMES, ACTUALLY BECOME SUPERSATURATED WITH OXYGEN. THIS PHENEMENON OF SUPERSATURATION IS USUALLY ASSOCIATED WITH DAYLIGHT HOURS IN EUTROPHIC LAKES HAVING THICK MASSES OF ROOTED PLANTS AND/OR ALGAE.

THROUGHOUT THE DAY, WHEN PLANTS ARE PHOTOSYNTHESIZING, ANIMALS IN THE LAKE SYSTEM ARE UTILIZING THE OXYGEN FOR RESPIRATION THAT IS BEING PRODUCED BY THE PLANTS. AT NIGHT, HOWEVER, PLANTS STOP PHOTOSYNTHESIZING AND BEGIN RESPIRING ALONG WITH THE OTHER ORGANISMS IN THE LAKE. THIS CHANGE IN THE ROLE OF PLANTS, FROM PRODUCERS OF OXYGEN TO CONSUMERS OF OXYGEN, CAN SERIOUSLY CHANGE THE O_2 CONCENTRATIONS IN A LAKE. WHEN LARGE FLUCTUATIONS IN O_2 OCCUR IN A LAKE ON A DAILY BASIS (WITH HIGH OXYGEN READINGS OCCURRING DURING THE DAY AND LOW O_2 CONCENTRATIONS AT NIGHT) THE LAKE IS SAID TO BE UNDERGOING A DIURNAL O_2 FLUCTUATION. (FIG. 5). DIURNAL FLUCTUATIONS OF OXYGEN MAY OR MAY NOT AFFECT ANIMAL SPECIES IN THE LAKE SYSTEMS, DEPENDING ON THE DEGREE OF FLUCTUATION. IF THE EXTREMES OF OXYGEN CONCENTRATION ARE TOO GREAT, THEN PHYSIOLOGICAL STRESS WILL AFFECT THE LARGER, MORE OXYGEN-SENSITIVE ORGANISMS. CONTINUED EXPOSURE TO STRESS CONDITIONS WILL RESULT IN GREATER SUSCEPTIBILITY OF THESE ORGANISMS TO DISEASE, LOWER REPRODUCTIVE RATES, AND A LOSS IN COMPETITIVENESS. THE ULTIMATE EFFECT COULD BE PREMATURE DEATH.

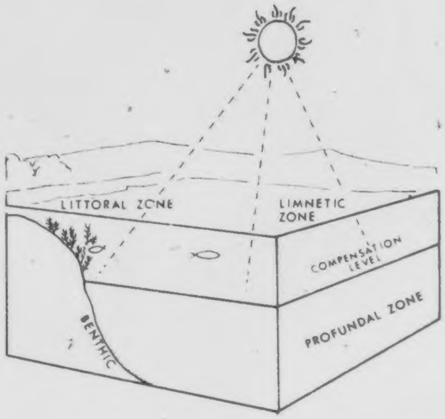

FIGURE 4. A GENERALIZED PICTURE OF THE LAKE IN MIDSUMMER SHOWING THE MAJOR ZONES. THE COMPENSATION LEVEL IS THE POINT AT WHICH THE LIGHT IS TOO LOW FOR PHOTOSYNTHESIS.

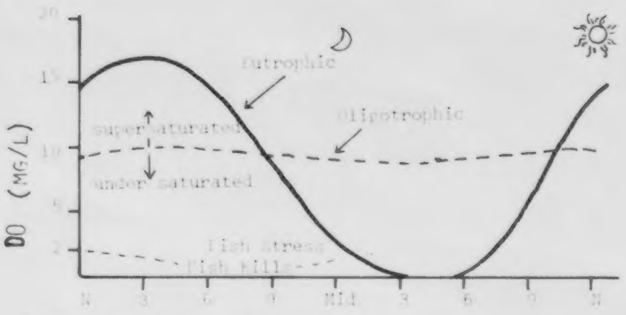

TABLE 5. A DIURNAL OXYGEN CURVE -- SUMMER

MEANWHILE, THE PART OF THE LAKE WHERE SUNLIGHT CANNOT PENETRATE IS CALLED THE TROPHOLYTIC ZONE; THIS ZONE CAN BE DIVIDED INTO TWO SUBZONES CALLED THE PROFUNDAL ZONE AND THE BENTHIC ZONE. BOTH OF THESE SUBZONES ROUGHLY CORRESPOND TO THE HYPOLMNION OF MOST LAKES. THE DIVERSITY AND ABUNDANCE OF LIFE IN THE PROFUNDAL ZONE IS STRONGLY INFLUENCED BY THE OXYGEN CONCENTRATION AND WATER TEMPERATURE OF THE WATER. ORGANISMS THAT LIVE HERE DEPEND ON THE "RAIN" OF ORGANIC MATERIAL WHICH IS SETTLING DOWN FROM THE PHOTOTROPHIC ZONE FOR THEIR FOOD -- AND THUS ENERGY -- SOURCE. WHEN A LAKE IS HIGHLY EUTROPHIC, DECOMPOSER ORGANISMS ARE SO ABUNDANT THAT THEY OFTEN DEPLETE THE PROFOUNDAL WATERS OF OXYGEN AND LITTLE AEROBIC LIFE CAN EXIST THERE.

IN THE BENTHIC ZONE (BOTTOM SEDIMENTS) DECOMPOSITION OF ORGANIC DEBRIS OCCURS AT A HIGHER RATE THAN ANYWHERE ELSE IN THE AQUATIC SYSTEM. OXYGEN DEMANDS ARE SO GREAT HERE THAT ONLY ANAEROBIC AND FACULTATIVE BACTERIA CAN EXIST. DECOMPOSITION PROCEEDS MUCH MORE SLOWLY AND INEFFICIENTLY AS A RESULT OF NO FREE OXYGEN. THE END RESULT IS AN ACCUMULATION OF DETRITAL MATERIAL ON THE BOTTOM OF THE LAKE; THIS PRODUCES A RICH SOURCE OF HYDROGEN SULPHIDE AND METHANE -- TWO NOXIOUS GASES.

FISH SPECIES AND SOME FORMS OF ZOOPLANKTON RESPOND TO LOW OXYGEN CONCENTRATIONS BY CONSCIOUSLY MOVING FROM OXYGEN DEFICIENT WATERS TO MORE FAVORABLE OXYGEN AREAS IN A LAKE (FIG. 6). IF, HOWEVER,

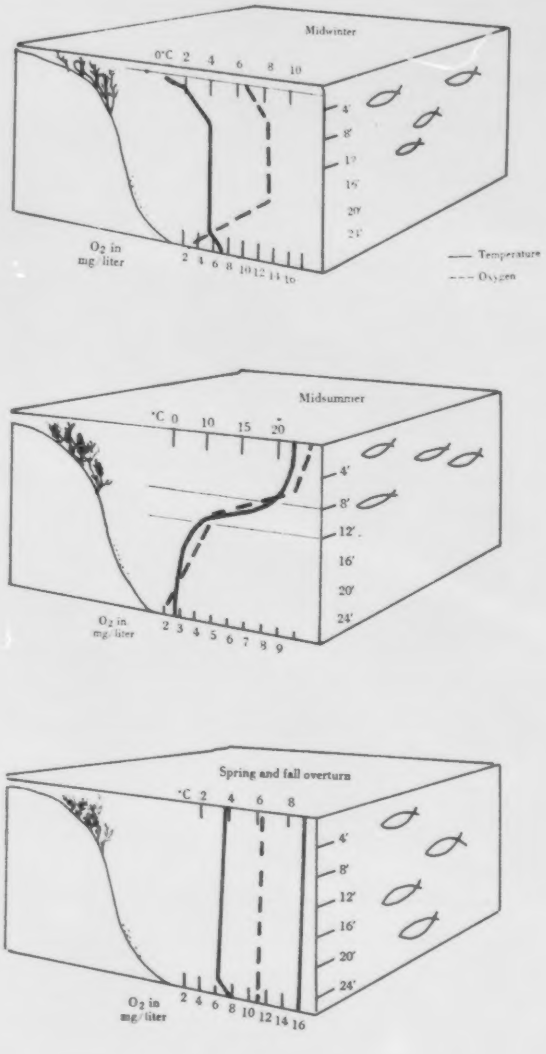
Midwinter
0°C 2 4 6 8 10
4'
8'
12'
16'
20'
24'
O₂ in mg/liter
2 4 6 8 10 12 14 16
Temperature
Oxygen
Midsummer
°C 0 10 15 20
4'
8'
12'
16'
20'
24'
O₂ in mg/liter
2 3 4 5 6 7 8 9
Spring and fall overturn
°C 2 4 6 8
4'
8'
12'
16'
20'
24'
O₂ in mg/liter
2 4 6 8 10 12 14 16

FIGURE 6. OXYGEN CURVES AND FISH DISTRIBUTION IN A TYPICAL LAKE DURING VARIOUS TIMES OF THE YEAR.

THE COMBINED EFFECTS OF LOW PHOTOSYNTHESIS AND HIGH RESPIRATION AND DECOMPOSITION OCCUR (AS IS COMMON IN EUTROHPIC LAKES DURING WINTER), THEN FISH SPECIES AND OTHER ORGANISMS ARE FORCED TO COMPETE WITH PLANTS AND BACTERIA FOR THE AVAILABLE FREE OXYGEN. THE END RESULT OF THIS COMPETITION CAN RESULT IN "FISH KILLS" IF OXYGEN CONCENTRATIONS BECOME TOO LOW.

MEASURING OXYGEN DEMANDING WASTES:

WHEN LARGE QUANTITIES OF OXYGEN DEMANDING COMPOUNDS LIKE DEAD ORGANIC MATTER OR LOW OXIDATION-STATE CHEMICALS, ARE PLACED IN A BODY OF WATER, FREE OXYGEN IS USED AS BIOLOGICAL PROCESSES (LIKE RESPIRATION AND DECOMPOSITION) AND CHEMICAL PROCESSES (LIKE OXIDATION) BEGIN ATTACKING THESE NEWLY INTRODUCED COMPOUNDS. THIS DEMAND FOR FREE OXYGEN REDUCES THE AMOUNT OF OXYGEN NORMALLY AVAILABLE TO AQUATIC ORGANISMS. IF TOO MUCH OXYGEN IS CONSUMED, ORGANISMS THAT DEPEND ON OXYGEN FOR LIFE PROCESSES GO INTO STRESS AND COULD DIE.

THE OXYGEN OR OXIDANT DEMAND OF A SUBSTANCE -- I.E., THE CAPACITY OF A SUBSTANCE TO DEPLETE AVAILABLE OXYGEN -- IS MEASURED BY SEVERAL METHODS. EACH METHOD MEASURES A FORM OF OXYGEN DEPLETION.

BIOCHEMICAL OXYGEN DEMAND (BOD) IS THE DETERMINATION OF THE AMOUNT OF OXYGEN USED IN THE AEROBIC, BIOCHEMICAL DECOMPOSITION OF A SUBSTANCE. A SAMPLE IS DILUTED WITH OXYGENATED WATER, SEEDED WITH A BACTERIAL CULTURE IF NECESSARY AND HELD IN THE DARK AT 20°C USUALLY FOR 5 DAYS (BOD_5). THE DECREASE IN DISSOLVED OXYGEN DURING THE INCUBATION PERIOD IS THEN CORRECTED FOR DILUTION AND THE RESULTS ARE EXPRESSED IN TERMS OF MILLIGRAMS OXYGEN USED PER LITER OF ORIGINAL SAMPLE (E.G., THE BOD_5 OF A SEWAGE SAMPLE MIGHT BE 230 MG/L; BOD_5 FOR LAKE WATER MIGHT BE 2 MG/L; AND FOR AGRICULTURAL OR INDUSTRIAL WASTES, 30,000 MG/L). BOD_{20} SIGNIFIES A MEASUREMENT OF OXYGEN DEMAND EXERTED OVER A PERIOD OF 20 DAYS RATHER THAN THE STANDARD 5-DAY TEST.

LOOSELY INTERPRETED, A BOD_5 OF 10 MG/L MEANS THAT 10 MG OF OXYGEN WOULD BE REDUCED/TRANSFORMED BY DECOMPOSITION (OR OXIDATION) OF MATERIALS IN ONE LITER OF WATER. IF LESS OXYGEN IS AVAILABLE, THE SYSTEM WILL BECOME ANOXIC (NO OXYGEN) AND ANAEROBIC (NO AIR) DECOMPOSITION PROCESSES WILL DOMINATE.

FOR SIMPLIFIED STREAM SYSTEMS RECEIVING WASTE LOADING FROM A POINT SOURCE, (ASSUME CERTAIN MIXING RATES, UNIFORMITY OF FLOW, KNOWN RELATIONSHIP BETWEEN ANALYTICAL BOD AND STREAM CHARACTERISTICS, ETC.) BOD MEASUREMENTS CAN BE USED TO PREDICT THE OXYGEN CONCENTRATIONS AT VARIOUS POINTS DOWNSTREAM USING A MATHEMATICAL MODEL. FLOW RATES, TEMPERATURE, MIXING AND AERATION COEFFICIENT DATA ARE COMBINED WITH BOD LOADING INFORMATION TO ESTIMATE THE PROFILE OF OXYGEN CONCENTRATIONS (OXYGEN SAG CURVE) DOWNSTREAM FROM WASTE SOURCES. MODELS LIKE THIS CAN BE USED TO *estimate* the maximum BOD loading which can be assimulated safely by the stream system, without seriously depleting the oxygen supply.

Chemical oxygen demand (COD) is a measure of the amount of oxygen which is chemically equivalent to the amount of a strong chemical oxidant (dichromate or permanganate) used to digest the "oxygen demand" in a sample. Wet chemical oxidation can provide estimates of pollutional loads more quickly than BOD determinations, but the results may not correspond (i.e., the COD of a sewage sample might be 300 mg/l when the BOD_5 is 230 mg/l) because of the difference in the effectiveness of the two methods in oxidizing individual substances.

COD is particularly useful in testing oxidant demand for wastes which inhibit or kill the organisms used in doing BOD analyses.

Since a major component of oxidant demand commonly is plant and animal products (organic substances containing carbon compounds), another measure of the potential impact of a waste on the dissolved oxygen system is to measure organic carbon. *Organic carbon* (total, TOC; dissolved, DOC) can be measured by driving off inorganic carbon and converting all organic carbon compounds to carbon dioxide at high temperatures. The amount of carbon dioxide released is measured to determine the organic carbon content of the sample. High organic carbon readings suggest high productivity (high biomass) in an aquatic ecosystem; high productivity, in turn suggests eutrophication conditions within the lake.

Municipal sewage, feedlots, food processing, pharmaceutical production, pulpwood processing and plant litter contribute organic carbon to waters.

Water quality criteria for oxygen are described either in terms of a minimum oxygen concentration or a minimum per cent of the oxygen saturation limit (which helps account for temperature variations). Protection of fish is an objective used in developing standards, usually the egg and larval stages are the most vulnerable to suffocation. Minimum values of 5 to 6 mg/l D.O. or 80% to 90% saturation are considered adequate for fish propagation in most cases.

The open-water areas of Lake Michigan nearly always meet the suggested oxygen levels. Harbor and bay waters where BOD loading is at a maximum and water circulation is at a minimum are most susceptible to oxygen deficiencies.

Other factors affecting oxygen concentrations in aquatic ecosystems:

Temperature -- As mentioned earlier, temperature affects the solubility (*amount*) of free oxygen in water. It follows, therefore, that temperature will also affect the *distribution* of oxygen in a lake system.

In the chapter on Lake Dynamics and Hydrology, a phenomenon known as thermal stratification in lake systems is discussed (pp. 37-39). Thermal stratification is important to the "liveability" of a lake system due to its effect on the oxygen concentrations at various levels within a lake.

If one were to observe the oxygen distribution during various seasons of the year, one would find that oxygen stratification during summer nearly parallels that of temperature stratification. In general (despite higher water temperatures and thus lower solubility), oxygen concentrations are at their highest near the surface of a lake due to the interchange between the water and atmosphere and high photosynthetic rates. The quantity of oxygen then begins to decrease with depth; this is caused, in part, by the respiration of fish and decomposer organisms but also because 1) the water is no longer in direct contact with the atmosphere and 2) photosynthetic rates are declining due to the scattering of light by water and various suspended particles. Some lakes (oligotrophic) may vary little in oxygen from top to bottom -- i.e., each layer will be saturated with oxygen relative to temperature and pressure: but others (particularly eutrophic lakes) will find high oxygen concentrations in the epilimnion and almost anoxic conditions in the hypolimnion.

During spring and fall turnover, water recirculates throughout the lake due to density differences created by the heating or cooling of the surface layer. Turnover results in the exposure of nearly all water in a lake system to the atmosphere. The ultimate effect is the replenishment of oxygen in the deep waters of a lake and the return of nutrients from the sediments (where decomposition has occurred) to the surface of the lake where photosynthesizing plants may utilize them.

Temperature also influences the oxygen levels in water by regulating several biological processes. Physiological activities of organisms are strongly influenced by temperature. For example, a gradual change in water temperature will trigger spawning and hatching. Growth rates will increase or decrease with temperature. Metabolic processes -- such as photosynthesis or respiration -- will approximately double with each 10°C increase in water temperature, until a temperature limit is finally reached where cellular damage occurs.

Because aquatic processes (physical, chemical, and biological) are highly temperature dependent, many researchers now consider thermal changes in aquatic systems a form of pollution. Changing the long-term average temperature, the maximum and minimum temperature, the diurnal variations, or the rate of temp-

ERATURE CHANGES CAN SERIOUSLY AFFECT BIOLOGICAL PROCESSES. RATES OF PURELY INORGANIC CHEMICAL REACTIONS WILL RESPOND TO TEMPERATURE CHANGES OVER A WIDE RANGE, BUT BIOCHEMICAL REACTIONS ARE RESTRICTED, OWING TO CELL DAMAGE OR DEATH OF ORGANISMS, OVER RELATIVELY SMALL TEMPERATURE RANGES.

THE GOOD NEWS ABOUT THERMAL POLLUTION IS THAT THERE ARE NO LONG LASTING RESIDUALS OR ACCUMULATIVE EFFECTS (IF THE INCREASES IN PLANT AND ANIMAL BIOMASS THAT MAY RESULT FROM HIGHER TEMPERATURES ARE IGNORED. WITH SOME FORETHOUGHT AS TO HEAT DISSIPATION, THE ADVERSE EFFECTS OF TEMPERATURE CHANGES IN AQUATIC ECOSYSTEMS ON SPECIFIC PLANTS AND ANIMALS CAN BE MINIMIZED. THE MOST COMMON SOURCES OF THERMAL POLLUTION IN THE LAKE MICHIGAN BASIN INCLUDE POWER PLANTS (NUCLEAR AND FOSSIL-FUEL), PAPER MILLS, FOOD PROCESSING PLANTS, AND STEEL INDUSTRIES.

WATER TRANSPARENCY -- LIGHT PENETRATION IN A BODY OF WATER IS STRONGLY AFFECTED BY THE TURBIDITY (SEE SECTION OF WATER POLLUTION LABELED "PARTICULATES") AND DISSOLVED COLORED MATERIALS. BOTH OF THESE FACTORS ARE RELATED TO THE OXYGEN CONCENTRATION OF A BODY OF WATER BY LIMITING PHOTOSYNTHESIS.

EXCESSIVE NUTRIENTS -- AS DISCUSSED EARLIER, EXCESSIVE NUTRIENTS AFFECT OXYGEN LEVELS IN AQUATIC SYSTEMS BY PRODUCING EXCESSIVE PLANT AND ANIMAL GROWTH (KNOWN COLLECTIVELY AS PRODUCTIVITY.) THIS EXCESSIVE PLANT/ANIMAL GROWTH MUST BE SUPPORTED BY AEROBIC RESPIRATION WHEN IT IS LIVING AND WILL EVENTUALLY FORM OXYGEN DEMANDING WASTES WHEN IT DIES AND BEGINS DECOMPOSITION, WHICH ALSO REQUIRES O_2. SUCH ACTIVITY (I.E., GROWTH, RESPIRATION, AND DECOMPOSITION) IS MEASURED AS BOD, COD, AND ORGANIC CARBON LEVELS IN LAKES.

HAZARDOUS SUBSTANCES

A HAZARDOUS SUBSTANCE IS ANY GAS, LIQUID OR SOLID THAT POSES A SUBSTANTIAL, PRESENT OR POTENTIAL THREAT TO LIFE. THE "THREAT" IS OFTEN THOUGHT OF ONLY IN TERMS OF SOMETHING THAT IS TOXIC OR POISONOUS, BUT ALSO INCLUDES CORROSIVE, FLAMMABLE, EXPLOSIVE, RADIOACTIVE, INFECTIOUS, CARCINOGENIC, MUTAGENIC OR OTHER ILLNESS-PRODUCING SUBSTANCES.

AS WATER POLLUTION CONCERNS HAVE EVOLVED FROM CONSIDERATION OF TURBIDITY, OXYGEN DEMAND AND PATHOGENS, TO MORE SUBTLE PARAMETERS LIKE RADIOACTIVITY AND SUBLETHAL TOXICITY, STANDARDS HAVE BECOME MORE DIFFICULT TO DEFINE. MEASUREMENTS OF POLLUTANT CONCENTRATIONS HAVE CHANGED FROM MILLIGRAM (10^{-3}g) LEVELS TO MICROGRAM (10^{-6}g) OR PICOGRAM (10^{-12}g) QUANTITIES. TEST ORGANISMS HAVE COME TO INCLUDE NOT ONLY THE MOST COMMON ONES WHICH ARE CONVENIENT (OR POSSIBLE) TO REAR UNDER LABORATORY CONDITIONS BUT ALSO THE RARE AND ENDANGERED SPECIES.

THE SOURCES OF HAZARDOUS SUBSTANCES WHICH AFFECT THE WATER RESOURCES OF STREAMS AND THE GREAT LAKES INCLUDE BOTH point and nonpoint classifications.

Point sources include discharges from municipal, industrial and commercial facilities. The amount of a *specific* toxic material may be measured and regulated, whether it comes in a liquid, solid or gaseous form. Industrial sources contribute the largest volume of toxic and hazardous wastes, particularly industries producing primary metals, organic chemicals, electroplated products, inorganic chemicals, textiles, refined oil products, rubber and plastics.

Nonpoint or diffuse *sources* are not easily measured or controlled. Stormwater runoff contains greases, oils, heavy metals (such as iron, nickel, cadmium, mercury, lead, zinc and chromium), pesticides, etc.

Toxic Substances:

Toxicity, like beauty, is specific to the beholder -- how much, of what, for how long, to whom, for what, and under what set of environmental conditions. In a cynical sense, *everything* is toxic to something under some set of conditions.

While natural processes can produce toxic conditions for specific organisms, control techniques need to be applied first to human activities which induce toxic aquatic environments.

Acute or immediate toxicity is measured in terms of a median tolerance limit (TL_M or TL_{50}) -- the concentration of substance in water at which 50 percent of the test animals are able to survive for a specified exposure time (usually 24, 48, or 96 hours) under a given set of conditions (e.g., pH, DO, temperature); or the lethal concentration (LC_{50}), the concentration at which 50 per cent of the animals do not survive in the specified time. The TL_M and LC_{50} are analogous to LD_{50} (50 per cent lethal *dose*) which is commonly used in toxicological testing where a dosage of substance is administered directly to a test animal.

Chronic or long-term toxicity is more difficult to define and measure. Long-term tests require keeping the test substances at a known and often low concentration and the test animals must be fed and wastes removed. Studies in testing tanks use a continuous flow of dosed water over long periods of time and can maintain the most constant conditions. More intensive studies determine chronic effects of specific substances on reproduction and growth or disease rates for several generations of a test organism. Results may be expressed in terms of the tolerance limit or lethal concentration, or cancer producing rates (carcinogenicity), formation of mutants (mutagenicity) and accumulation of the test substance in the organism or specific parts of the organism (bioaccumulation or biomagnification).

It is readily apparent that definitive testing for all the combinations of toxicants, organisms, toxic effects, time

AND ENVIRONMENTAL CONDITIONS HAVE NOT BEEN OR CANNOT BE DONE. FOR MANY SUBSTANCES, SUCH AS THE METAL IONS, THE CHEMICAL FORM IS A CRITICAL FACTOR. ONE FORM (THE HEXAVALENT OXIDATION STATE) OF CHROMIUM, FOR INSTANCE, IS MANY TIMES MORE TOXIC TO ANIMALS THAN OTHER FORMS. STABLE COMPLEXES ARE FORMED WHICH CAN ENHANCE OR COMPLETELY NEGATE A METAL'S TOXICITY.

A FURTHER FRUSTRATION IS THE ATTEMPT

TOXIC SUBSTANCES

PROCESSES	ARSENIC	CADIUM	CHLORINATED HYDROCARBONS	CHROMIUM	COPPER	CYANIDES	LEAD	MERCURY	MISCELLANEOUS ORGANICS**	SELENIUM	ZINC	PHTHALATE ESTERS
MINING & METALLURGY	X	X		X	X	X	X	X		X	X	
PAINT & DYE		X		X	X	X	X	X	X	X		
PESTICIDE	X		X			X	X	X	X			X
ELECTRICAL & ELECTRONIC			X		X	X	X	X		X		
PRINTING & DUPLICATING	X			X	X		X		X	X		
ELECTROPLATING & METAL FINISHING		X		X	X	X					X	
CHEMICAL MANUFACTURING			X	X	X			X	X			X
EXPLOSIVES	X				X		X	X	X			
RUBBER & PLASTICS			X			X		X	X		X	X
BATTERY		X					X	X			X	
PHARMACEUTICAL	X							X	X			
TEXTILE				X	X				X			
PETROLEUM & COAL	X		X				X					
PULP & PAPER								X	X			
LEATHER				X					X			
COOLING				X	X				X			

* INCLUDING POLYCHLORINATED BIPHENYLS, PESTICIDES

** E.G.: ACROLEIN, CHLOROPICRIN, DIMETHYL SULFATE, DINITROBENZENE, DINITROPHENOL, NITROANILINE, AND PENTACHLOROPHENOL, SOLVENTS

TABLE 4 SUMMARY OF PROCESSES AND RELATED TOXIC SUBSTANCES

TO ACCURATELY EXTRAPOLATE RESULTS FROM ONE TEST ORGANISM TO ANOTHER, PARTICULARLY TO HUMANS.

TABLE 4 SUMMARIZES SOME OF THE TOXIC CHEMICAL GROUPINGS AND PROCESSES WHICH MAY LEAD TO THEIR DISTRIBUTION IN WATER. ADDITIONAL INFORMATION ON THIS ASPECT OF WATER QUALITY CAN BE FOUND IN THE SECTION ON TOXIC SUBSTANCES AND HUMAN HEALTH.

PETROLEUM PRODUCTS:

ESSENTIALLY ALL OF THE DISSOLVED OR FLOATING OILS, GREASES AND OTHER PETROLEUM PRODUCTS (PETROLEUM HYDROCARBONS, PHC) IN LAKE WATER ARE RELATED TO CULTURAL ACTIVITIES, ALTHOUGH SOME OILS ARE DERIVED FROM THE DECOMPOSITION OF AQUATIC PLANTS AND ANIMALS. CITY HARBOR AREAS ACCUMULATE THE GREATEST CONCENTRATIONS OF GREASE AND OILS, BUT THE RELATIVE CONTRIBUTIONS OF THESE CONCENTRATIONS FROM OIL SPILLS, BILGE PUMPAGE, INDUSTRIAL AND MUNICIPAL WASTES, URBAN RUNOFF AND OTHER SOURCES HAVE NOT BEEN MEASURED.

PETROLEUM PRODUCTS IMPART NUISANCE TASTES AND ODORS TO INDUSTRIAL AND MUNICIPAL WATER SUPPLIES. REMOVAL REQUIRES ADDITIONAL TREATMENTS SUCH AS SORPTION ONTO ACTIVATED CARBON. FISH AND WATERFOWL FLESH DERIVES OFF-FLAVORS FROM CONTACT WITH OILS AND GREASES. BESIDES THE OBVIOUS ESTHETIC EFFECTS, FLOATING SLICKS OR FILMS COAT HULLS OF SHIPS AND BOATS, AFFECT THE BUOYANCY OF WATER BIRDS, INTERFERE WITH RESPIRATION OF PLANTS AND ANIMALS, DESTROY SPAWNING GROUNDS AND ADVERSELY AFFECT THE OXYGEN STATUS OF WATER BY 1) EXERTING A HIGH OXYGEN DEMAND AND 2) INTERFERING WITH NORMAL GAS EXCHANGE AT THE AIR-WATER SURFACE. IN SEVERE CASES, PETROLEUM PRODUCT POLLUTION DEVELOPS INTO A FIRE HAZARD. RESUSPENSION OF BOTTOM SEDIMENTS BY WIND, BOATS OR DREDGING MAY RELEASE ATTACHED GREASE AND OILS, THEREBY RECONTAMINATING NEAR-SHORE WATERS.

WATER QUALITY STANDARDS CALL FOR GREASE AND OIL TO BE "VIRTUALLY ABSENT" OR "NOT VISIBLE", BUT HYDROCARBON ODORS AND TASTES MAY STILL BE PRESENT EVEN WHEN THE ANALYTICAL VALUES FOR GREASE AND OIL ARE VERY LOW. CONCENTRATIONS IN HARBOR WATERS OF TENS OF MG/L HAVE BEEN OBSERVED, BUT AVERAGES OF LESS THAN 10 MG/L ARE COMMON. ANALYTICAL VALUES SUCH AS THESE MAY BE MISLEADING BECAUSE OF PROBLEMS WITH TAKING ACCURATE SAMPLES OF WATER WHICH HAS AN OIL FILM ON THE SURFACE.

A SUMMARY OF TOXIC EFFECTS PETROLEUM PRODUCTS TO AQUATIC ORGANISMS IS PRESENTED IN "QUALITY CRITERIA FOR WATER" (EPA, 1972). THE PETROLEUM PRODUCT LIST INCLUDES SOLUBLE HYDROCARBONS, DISPERSANTS, NO. 2 FUEL OIL, FRESH CRUDE FROM A VARIETY OF SOURCES, GASOLINE, DIESEL FUEL, REFINERY EFFLUENTS, WASTE OIL, LUBRICANTS, WEATHERED CRUDE, RESIDUALS, TOLUENE, BENZENE, KEROSENE AND "OIL". AT SUBLETHAL CONCENTRATIONS, THE SUMMARY NOTES GROWTH DEPRESSION, CHANGES IN PHOTOSYNTHESIS, CHANGES IN RESPIRATION RATES, DELAY OF MOLTING, CHANGES IN EGG DEVELOPMENT, AND INHIBITION OF FEEDING AS EVIDENCE OF BIOLOGICAL

EFFECTS OF PETROLEUM PRODUCTS ON A VARIETY OF ORGANISMS.

RADIOACTIVITY:

SINCE THE EXPOSURE OF LIVING TISSUE TO (IONIZING) RADIATION IS RECOGNIZED AS BEING INJURIOUS (MUTOGENIC, CARCINOGENIC), EVEN FROM THE ARRAY OF NATURALLY-OCCURRING RADIOACTIVE ELEMENTS FOUND IN WATER, EFFORTS ARE MADE TO MINIMIZE THE ADDITIONAL EFFECTS OF RADIOACTIVITY FROM WASTES.

EACH ELEMENT HAS A SPECIFIC NAME AND ATOMIC NUMBER RELATED TO THE NUMBER OF PROTONS IN THE NUCLEUS OF ITS ATOM. A SPECIFIC ELEMENT MAY HAVE SEVERAL ISOTOPES, SOME OF WHICH MAY BE RADIOACTIVE, THAT DIFFER ONLY IN THEIR ATOMIC WEIGHT. HYDROGEN, FOR INSTANCE, HAS AN ATOMIC NUMBER OF ONE, BUT HAS THREE ISOTOPES, H-1, H-2, AND H-3, WHERE THE NUMBERS TELL THE ATOMIC WEIGHT. ALL THREE ISOTOPES OCCUR NATURALLY, BUT THE H-1 FORM IS BY FAR THE MOST COMMON. THE H-3 FORM IS THE ONLY ONE WHICH IS RADIOACTIVE. UPON DISINTEGRATION, BETA RADIATION IS RELEASED. WHEN SPECIFIC RADIO-ISOTOPES ARE DESCRIBED, THE ATOMIC WEIGHT IS USED TO DENOTE THE EXACT ISOTOPE, ASSURING THAT EVERYONE IS TALKING ABOUT THE SAME COMPONENT. EACH RADIOISOTOPE EMITS A CERTAIN KIND OF RADIATION.

RADIOACTIVE ENERGY CAN BE RELEASED DURING CHANGES WITHIN A NUCLEUS, EMITTING 1) ALPHA RADIATION (A POSITIVELY CHARGED HELIUM NUCLEI), 2) BETA RADIATION (ELECTRONS OR POSITRONS), OR 3) GAMMA RADIATION (ELECTROMAGNETIC WAVE ENERGY SIMILAR TO X-RAYS). IN GENERAL, ALPHA RADIATION IS NOT VERY PENETRATING (A FEW CENTIMETERS IN AIR), BUT PRODUCES MUCH DAMAGE IN A SHORT TRIP; BETA RADIATION IS MORE PENETRATING BUT PRODUCES LESS DAMAGE (IONIZATION) AND GAMMA RADIATION IS HIGHLY PENETRATING AND QUITE DAMAGING. THE THREE FORMS OF RADIATION ARE ANALAGOUS TO BEING HIT WITH A SHOVEL (ALPHA; LOW PENETRATION, MUCH DAMAGE), A PENCIL (BETA) AND A SPEEDING ARROW (GAMMA; HIGH PENETRATION WITH MODERATE DAMAGE ALL THE WAY THROUGH).

RADIOACTIVE ELEMENTS (RADIOISOTOPES) REACT CHEMICALLY AND BIOLOGICALLY IN EXACTLY THE SAME WAYS AS THEIR STABLE (NON-RADIOACTIVE) EQUIVALENTS. WATER HAVING RADIOACTIVE HYDROGEN ATOMS (H-3) LOOKS, SMELLS, FEELS AND TASTES LIKE WATER FORMED FROM THE STABLE HYDROGEN ATOMS. THEIR EFFECT ON ORGANISMS, HOWEVER, CAN BE DEVASTATING. EXPOSURE TO RADIOACTIVE SUBSTANCES, ESPECIALLY SUBSTANCES PRODUCING GAMMA RADIATION, CAN CAUSE MUTATIONS IN OFFSPRING BY ALTERING GENETIC MATERIALS. STRONTIUM, WHICH REACTS MUCH LIKE CALCIUM, IS LIKELY TO CONCENTRATE IN BONES, OR TO BE PASSED ALONG IN MILK. CONTAMINATED ORGANISMS WILL NOT GLOW IN THE DARK, BUT INTERNAL CHANGES MAY BE SEVERE.

RADIOISOTOPES IN AQUATIC SYSTEMS CYCLE THROUGH THE SEDIMENT, WATER, PLANT AND ANIMAL PHASES ALONG WITH THEIR STABLE COUNTERPARTS. PLANTS AND ANIMALS BECOME ESPECIALLY SIGNIFICANT IN THE CYCLING IF THEY TEND TO CONCENTRATE A RADIOISOTOPE AND PASS IT ALONG THE FOOD WEB TO A CON-

SUMER WHERE IT BECOMES HAZARDOUS.

THE PRINCIPLE SOURCES OF RADIOACTIVE WASTES ARE POWER PLANTS, INDUSTRIAL WASTES, MEDICAL FACILITIES AND RESEARCH LABORATORIES.

BACTERIA

BACTERIAL CONTAMINATION OF SURFACE WATERS MAY OR MAY NOT BE CONSIDERED A POLLUTANT DEPENDING ON: 1) THE NATURE (KIND) AND QUANTITY OF BACTERIA PRESENT; AND 2) THE INTENDED USE OF THE BODY OF WATER. OBVIOUSLY, IF A PARTICULAR STREAM OR LAKE IS TO BE USED FOR PUBLIC WATER SUPPLY PURPOSES, A MINIMUM AMOUNT OF ALL KINDS OF BACTERIA IS DESIRED; IF, HOWEVER, THE WATER SUPPLY IS TO BE USED FOR INDUSTRIAL COOLING, BACTERIAL CONCENTRATIONS ARE GENERALLY NOT CONSIDERED A PROBLEM UNLESS THEY CREATE UNDESIRABLE "SLIME" FORMATIONS IN THE INTERIOR OF PIPING.

IT IS IMPORTANT TO NOTE THAT BACTERIA CAN SERVE A VERY POSITIVE ROLE IN AQUATIC SYSTEMS (BY PROVIDING THE CRITICAL SERVICE OF DECOMPOSING AND THUS RECYCLING OUR ORGANIC WASTES IN OUR ENVIRONMENT) AS WELL AS A NEGATIVE ROLE BY POSING INDUCING DISEASE AND POSING OTHER HEALTH PROBLEMS. LET'S CONSIDER THE FIRST FUNCTION BRIEFLY AND THEN MOVE ON TO THE PROBLEM AREAS THAT BACTERIA CREATE.

BACTERIA ARE A CRITICAL PART OF THE PROCEDURE OF RECYCLING IN THE ENVIRONMENT. ELEMENTS LIKE NITROGEN, PHOSPHORUS, CARBON, OXYGEN, MAGNESIUM, AND MANY OTHERS, ARE RELEASED BY BACTERIA AS LARGE ORGANIC MATERIALS LIKE FECAL WASTES, DEAD ANIMAL AND PLANT TISSUES, ETC., ARE INGESTED AND BROKEN DOWN IN RESPIRATION. THIS PROCESS IS KNOWN AS DECOMPOSITION AND IS ILLUSTRATED IN FIG. 7.

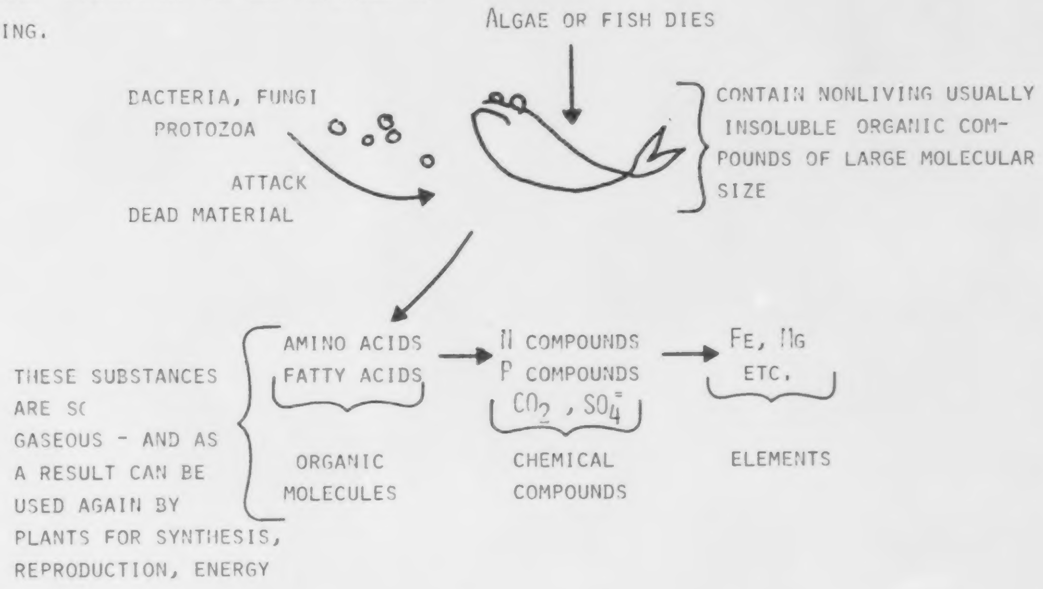
ALGAE OR FISH DIES
BACTERIA, FUNGI
PROTOZOA
ATTACK
DEAD MATERIAL
CONTAIN NONLIVING USUALLY INSOLUBLE ORGANIC COMPOUNDS OF LARGE MOLECULAR SIZE
AMINO ACIDS
FATTY ACIDS
ORGANIC MOLECULES
N COMPOUNDS
P COMPOUNDS
CO2 , SO4=
CHEMICAL COMPOUNDS
FE, MG
ETC.
ELEMENTS
THESE SUBSTANCES ARE SC GASEOUS - AND AS A RESULT CAN BE USED AGAIN BY PLANTS FOR SYNTHESIS, REPRODUCTION, ENERGY

FIGURE 7. ROLE OF BACTERIA IN RECYCLING NUTRIENTS VIA DECOMPOSITION.

WITHOUT THE SERVICE THAT BACTERIA PROVIDE IN DECOMPOSING ORGANIC MATERIALS TO RELATIVELY SMALL, REUSEABLE SUBSTANCES, MAN WOULD HAVE A SOLID-WASTE DISPOSAL PROBLEM THAT DEFIES IMAGINATION. THE PROCESS OF DECOMPOSITION BY BACTERIA REQUIRES A WATER MEDIA FOR FOOD TRANSPORTATION AND RESPIRATION PROCESSES. SINCE WATER IS A PART OF AIR, SOIL, AND AQUATIC ECOSYSTEMS, BACTERIA ARE EXTREMELY ABUNDANT IN OUR NATURAL ENVIRONMENT AND SHOULD BE CONSIDERED A NATURAL COMPONENT OF THE ECOSYSTEM.

IN DENSELY POPULATED AREAS, WATER POLLUTION BY CERTAIN KINDS OF BACTERIA IN SEWAGE CAN CREATE SEVERAL SERIOUS DISEASES INCLUDING TYPHOID FEVER AND A GROUP OF INTESTINAL DISORDERS GENERALLY CALLED "DYSENTERY" AS WELL AS SEVERAL MINOR HEALTH PROBLEMS LIKE EYE, EAR, NOSE INFECTIONS, SKIN INFLAMMATIONS, ETC. (SEE SECTION ON WATER SUPPLY FOR AN EXPANSION OF THIS TOPIC.)

THE DETECTION OF MANY OF THE ACTUAL CAUSATIVE MICROORGANISMS, SUCH AS SALMONELLA TYPHOSA, WHICH PRODUCES TYPHOID FEVER, IS EXTREMELY DIFFICULT BECAUSE OF THE RELATIVELY LOW CONCENTRATIONS OF THESE ORGANISMS NEEDED TO PRODUCE PROBLEMS VIA WATER CONTAMINATION, AND/OR THE LACK OF SUITABLE METHODOLOGIES TO IDENTIFY OR ISOLATE THESE ORGANISMS. CONSEQUENTLY, HEALTH AUTHORITIES ROUTINELY CHECK FOR THE PRESENCE OF CERTAIN BACTERIA THAT ARE KNOWN TO ASSOCIATE WITH DISEASE PRODUCING BACTERIA SUCH AS SALMONELLA; THESE BACTERIA ARE CALLED "INDICATOR ORGANISMS" AND THEY COMPRISE A GROUP OF BACTERIA KNOWN AS "COLIFORM BACTERIA".

COLIFORM BACTERIA DO NOT, IN THEMSELVES, CREATE DISEASE. THE FACT, HOWEVER, THAT THEY ARE DERIVED FROM THE INTE-

BACTERIA	SYMPTOM	OCCURRENCE IN U.S.	SOURCE
SALMONELLA TYPHOSA	TYPHOID FEVER	LOW TO NON-EXISTENT	HUMAN FECES
SALMONELLA PARATYPHI	ACUTE DIARRHEA & VOMITING		HUMAN FECES
SALMONELLA CHLEORAESUIS			SWINE FECES
SALMONELLA TYPHIMURIUM	"		RODENT FECES
SHIGELLA	BACILLARY DYSENTERY (DIARRHEA)	LOW	HUMAN FECES
VIBRIO COMMA	CHOLERA	LOW	HUMAN FECES
STAPHLOCOCCUS AUREUS	ACUTE GASTROENTERITIS	LOW	CONTAMINATED FOOD
PSEUDOMONOS AERUGINOSA	EAR, NOSE AND THROAT INFECTIONS	MEDIUM TO LOW	SKIN LESIONS FECES OR SKIN INFECTIONS

TABLE 5. BACTERIA KNOWN TO CONTAMINATE WATER SUPPLIES THAT ARE NOT DISINFECTED AND INDUCE CERTAIN HUMAN MALADIES.

STINES OF MAN AND ANIMALS -- THE SAME SOURCE AS DISEASE-PRODUCING BACTERIA -- IS USED TO IDENTIFY SITES WHERE FECAL CONTAMINATION OF WATER SUPPLIES IS OCCURRING. THE SOURCE OF THE FECAL CONTAMINATION CAN THEN BE TRACED BY EXAMINING VARIOUS CONTRIBUTORS TO THE STREAM OR LAKE WATER SUPPLY.

FECAL COLIFORM ARE USED AS INDICATORS OF POLLUTION BECAUSE THEY ARE MUCH MORE RESISTANT TO DEATH THAN THE ACTUAL DISEASE PRODUCERS AND BECAUSE THEY ARE EXTREMELY ABUNDANT IN AREAS WHERE FECAL CONTAMINATION IS OCCURRING. TABLE 5 IS AN ATTEMPT TO LIST SOME OF THE MOST COMMONLY KNOWN DISEASE PRODUCING BACTERIA.

VIRAL POPULATION

ONLY ONE VIRUS HAS BEEN DOCUMENTED AS BEING A WATERBORNE PATHOGEN -- THE VIRUS THAT CAUSES INFECTIOUS HEPATITIS. NUMEROUS OUTBREAKS OF INFECTIOUS HEPATITIS HAVE BEEN TRACED TO FECAL CONTAMINATION OF SHELLFISH BEDS OR DRINKING WATER SUPPLIES. ALMOST NOTHING IS KNOWN ABOUT THE VIRUS. ITS IDENTIFICATION IS ACCOMPLISHED BY THE SYMPTOMS IT PRODUCES -- I.E., YELLOW JAUNDICE OF THE SKIN, VOMITING AND ABDOMINAL PAIN.

THE HEPATITIS VIRUS IS COMMON THROUGHOUT THE WORLD. IN THE UNITED STATES, NEARLY 60,000 PEOPLE CONTRACT THE DISEASE EACH YEAR. MOST OF THESE CASES ORIGINATE IN SHELLFISH CONTAMINATED WITH FECES CONTAINING THE VIRUS. CONTROL INCLUDES ADEQUATE TREATMENT OF SEWAGE AND WATER AND THE COOKING OF SHELLFISH BEFORE INGESTION.

OTHER VIRUSES THAT MAY BE TRANSMITTED BY WATER (BUT LACK ADEQUATE DOCUMENTATION TO DATE) ARE THE VIRUSES BELONGING TO THE PICORNA GROUP THAT LIVE IN THE INTESTINE. THESE VIRUSES INCLUDE THE POLIO VIRUS, WHICH CAUSES POLIOMYELITIS; AND THE COXSACKIE AND ECHO VIRUSES THAT CAUSE MILD INTESTINAL DISORDERS. ALL OF THESE VIRUSES ARE COMMONLY FOUND IN HUMAN FECES AND PERSIST IN UNTREATED WATER FOR LONG PERIODS OF TIME. THEIR ROLE, HOWEVER, IN DISEASE INDUCEMENT IS PRESENTLY UNKNOWN.

AQUATIC COMMUNITIES

THE USE OF AQUATIC COMMUNITIES AS INDICATORS OF WATER QUALITY IS NOT A NEW CONCEPT. ALL LIVING ORGANISMS AND POPULATIONS OF ORGANISMS ARE SENSITIVE TO CHANGES IN THE CHEMICAL AND PHYSICAL ASPECTS OF THEIR ENVIRONMENT. SOME ORGANISMS CAN LIVE IN A WIDE VARIETY OF ENVIRONMENTS WHILE OTHERS HAVE VERY SPECIFIC REQUIREMENTS AND PROSPER ONLY UNDER A NARROW RANGE OF CHEMICAL AND PHYSICAL CONDITIONS. POPULATIONS WHICH CHARACTERIZE AN ENVIRONMENT ARE REFERRED TO AS COMMUNITIES AND ARE A REFLECTION OF THE COMPLEX INTERACTIONS OF THE CHEMICAL, PHYSICAL, AND BIOLOGICAL FACTORS WHICH MAKE UP THEIR ENVIRONMENT.

THERE EXISTS IN THE NATURAL WORLD A WIDE VARIETY OF AQUATIC ENVIRONMENTS, IRRESPECTIVE OF MAN'S INFLUENCE. CONSEQUENTLY, THERE EXISTS A WIDE VARIETY OF ORGANISMS WHICH CAN PROSPER IN THESE ENVIRONMENTS. BECAUSE OF THIS RESPONSE OF LIFE FORMS (BIOTA) TO THE AQUATIC ENVIRONMENT, BIOLOGY HAS AN IMPORTANT ROLE IN THE CHARACTERIZATION OF WATER QUALITY. THE COMPOSITION OF AQUATIC ORGANISMS IN TERMS OF SPECIES DIVERSITY (I.E., -- NUMBER OF DIFFERENT KINDS OF ORGANISMS) AND SPECIES' NUMBERS (ACTUAL NUMBER OF A SPECIFIC KIND OF ORGANISM -- BIOMASS) IS STRONGLY INFLUENCED BY CHEMICAL AND PHYSICAL ASPECTS OF THE ENVIRONMENT AND THUS ARE OFTEN CONSIDERED WHEN QUESTIONS CONCERNING WATER QUALITY ARISE.

THE IDEA THAT THE PRESENCE OF PARTICULAR ORGANISMS OR POPULATIONS OF ORGANISMS CAN BE USED AS AN INDICATOR OF WATER QUALITY -- THAT IS, THE "INDICATOR ORGANISM CONCEPT" -- HAS HAD A RELATIVELY LONG AND CONTROVERSIAL HISTORY. KALKWITZ AND MARSSON IN THE EARLY 1900'S FIRST INTRODUCED THE CONCEPT. IN ITS SIMPLEST FORM, IT SUGGESTS THAT THE PRESENCE OF A PARTICULAR SPECIES IS INDICATIVE OF CERTAIN ENVIRONMENTAL CONDITIONS THAT INTEREST MAN, WHEREAS ITS ABSENCE IS INDICATIVE OF THE ABSENCE OF THESE CONDITIONS.

WE KNOW NOW THAT IT IS RISKY TO TAKE THIS SIMPLIFIED APPROACH TO CHARACTERIZING AQUATIC CONDITIONS, AND THAT IN FACT, IT TAKES LABORIOUS AND THOROUGH STUDIES OF ALL ASPECTS OF THE AQUATIC COMMUNITY (I.E., NUMBER, KINDS, DISTRIBUTION OF ORGANISMS, PHYSICAL CHARACTERISTICS, CHEMICAL CHARACTERISTICS) TO ACCURATELY ASSESS THE WATER QUALITY OF A PARTICULAR LAKE OR STREAM.

NO PRETENSE SHOULD BE MADE THAT THERE IS AN EASY AND SHORT ROUTE TO CHARACTERIZE WATER QUALITY THROUGH A SIMPLE SMAPLING OF THE ORGANISMS WHICH EXIST IN A PARTICULAR BODY OF WATER. RATHER, AN EXAMINATION OF THE DIVERSITY OF AQUATIC ORGANISMS PRESENT (NUMBER OF DIFFERENT SPECIES) AS WELL AS THE TOTAL BIOMASS PRODUCED BY EACH SPECIES WILL HELP TO INDICATE WHETHER A BODY OF WATER IS UNDERGOING EUTROPHICATION. IN HIGHLY EUTROPHIC WATERS, THERE IS USUALLY FEWER SPECIES OF GREATER NUMBERS PRESENT THAN IN OLIGROPHIC WATERS WHERE PHYSICAL AND CHEMICAL CONDITIONS FAVOR MANY SPECIES OF FEWER NUMBERS AND THUS LESS BIOMASS DUE TO THE LOW PRODUCTIVITY OF THE LAKE OR STREAM.

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GLOSSARY

AQUATIC ECOSYSTEM: life, and the chemical and physical characteristics that affect that life, in a surface water body.

BLACK BOX MODEL: an equation, or set of equations, that describe a system only in terms of the inputs to, and the outputs from, that system.

COMPLETELY-MIXED: a situation in which the concentration of materials is uniform throughout.

CULTURAL EUTROPHICATION: nutrient enrichment of a water body due to human activities.

EMPIRICAL LAKE MODEL: an equation, or set of equations, derived from data on lakes, that describe the behavior exhibited in the data.

HYDROLOGY: a term referring to the properties, distribution and circulation of water.

MASS BALANCE: the process of summing all inputs to, and outputs from, a system (for a particular material, like phosphorus).

MATHEMATICAL MODEL: an equation, or set of equations, that describe the behavior of a physical system.

MICROGRAMS PER LITER: this is equivalent to 1000 times the milligrams per liter or 1000 times the parts per million.

MORPHOMETRY: a term referring to the form and structure of a system.

PHOSPHORUS LOADING: the total mass (amount) of phosphorus that enters a lake in a year.

PHYSICAL MODEL: a material (and not mathematical) representation of a system.

STEADY-STATE: a situation in which the characteristics of a system do not change over time.

WATERSHED: a region defined as the total area drained by a particular lake or river.

LAKE MODELING FOR DECISION MAKING

An increase in population, changes in technology, and improvements in the standard of living have all had a significant impact on environmental quality in the United States and Canada. This is certainly true for the St. Lawrence Great Lakes, where a variety of water quality problems have resulted from this developmental stress. One of the water quality problems that has been experienced in all five Great Lakes is cultural eutrophication, or nutrient enrichment of the lakes. Cultural eutrophication has been attributed largely to culturally-induced additions of nitrogen and phosphorus to lakes, particularly phosphorus. This dominance by phosphorus results from the fact that plant and algal growth in relatively unpolluted lakes is stimulated most often by phosphorus.

Fortunately, phosphorus is also one of the more "manageable" nutrients because it does not exist in a gaseous state for the most part. This means that virtually all of the phosphorus introduced into a water body comes from the land. While man can have little impact on the introduction of material to a lake as a gas from the atmosphere (which is one way nitrogen and carbon enter a lake), he does have the capability to control much of the phosphorus coming into a lake from the land. How, and to what extent this is done, is an issue that requires careful study and planning, since financial and social impacts may result. One technique that has been used to study nutrient inputs is the mathematical model.

A mathematical model is a mathematical equation, or set of equations, that translates a conceptual understanding of the system of interest into quantitative terms. It is different from a physical model, which is a material representation of the system. Mathematical models include extremely simple equations like $Y=AX$, as well as sophisticated systems of differential equations that require a relatively large computer for solution. In either case, though, the mathematical model is a simplification, or an approximation, of the real world system it is designed to model. Therefore, the results of the modeling process are approximate, or uncertain to some degree. This is an important aspect of modeling, and it is addressed later in this paper.

The mathematical model has become a useful technique in water quality management because of its efficiency in organizing, summarizing, and presenting information. As a simplified representation of reality, a successful model must embody a good summary of the system that it mimics. It must be an organized representation of the system, since it must logically portray the interactions among the parts of the system being modeled. In describing these interactions, it can be used to present information efficiently in equation form. Even if a particular model cannot be used to predict the behavior of a system with a high degree of precision, the development and application of this model can yield insight on how the system is organized and how the individual parts operate.

Many people who have some familarity with mathematical models envision a set of complex mathematical equations requiring computer solution when the term "mathematical model" comes to mind. While there are lake models of this type, most of the lake models seriously considered for policy evaluation are quite simple. This is because the simpler models are less costly to use, less prone to errors caused by man's incomplete knowledge of the aquatic ecosystem, and more understandable by planners and decision-makers who must use the model results. Nonetheless, for the sake of completeness, both the complex and simple models will be discussed herein.

The Aquatic Ecosystem Model

In order to develop or describe a complex lake model, a diagram like Figure 1 is needed to present a conceptual understanding of an aquatic ecosystem. This type of diagram is used to facilitate the development of a mathematical model of the aquatic ecosystem by expressing the hypothesized interactions among the components in the diagram. A model can then be constructed by writing mathematical equations to describe the interactions which are represented in Figure 1 by arrows.

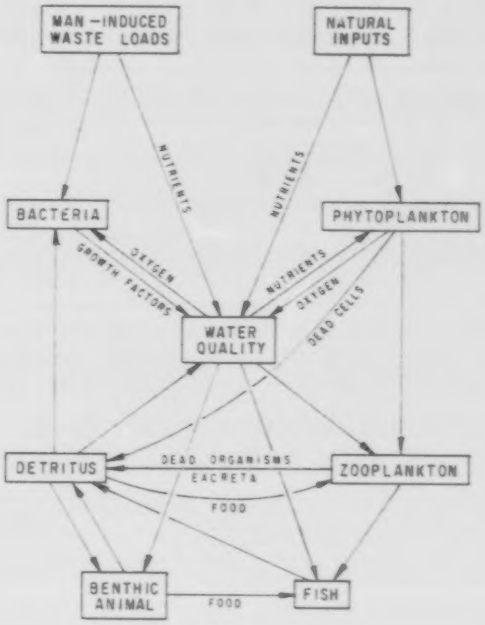
MAN-INDUCED WASTE LOADS
NATURAL INPUTS
NUTRIENTS
NUTRIENTS
BACTERIA
PHYTOPLANKTON
OXYGEN
GROWTH FACTORS
NUTRIENTS
OXYGEN
DEAD CELLS
WATER QUALITY
DETRITUS
DEAD ORGANISMS
EXCRETA
ZOOPLANKTON
FOOD
BENTHIC ANIMAL
FOOD
FISH

Figure 1. A Diagram of An Aquatic Ecosystem (from Chen and Orlob, 1972)

This type of model is called an aquatic ecosystem model. Like any new product, a model should be tested after it is constructed. This may involve the application of the model to a particular lake, and comparison of the model predictions with observed conditions. Through this comparison, the modeler can test the assumptions about

THE STRUCTURE AND FUNCTIONS OF THE AQUATIC ECOSYSTEMS INHERENT IN FIGURE 1. A GOOD CORRESPONDENCE BETWEEN PREDICTED AND OBSERVED VALUES CORROBORATES THE MODEL AS BEING CORRECT; A POOR CORRESPONDENCE IMPLIES THAT THE MODELER SHOULD RE-EVALUATE HIS/HER CONCEPTION OF THE SYSTEM.

FIGURE 1 IS AN EXAMPLE OF ONE WAY OF DESCRIBING HOW AN AQUATIC ECOSYSTEM MODEL WORKS. THIS TYPE OF MODEL IS CHARACTERIZED BY THE INCLUSION OF BIOLOGICAL COMPONENTS (E.G., PHYTOPLANKTON, BACTERIA, ETC.) AND THE MAJOR PLANT AND ALGAL NUTRIENTS (E.G., PHOSPHORUS, NITROGEN, AND CARBON). AN ECOSYSTEM MODEL GENERALLY CONSISTS OF SEVERAL EQUATIONS AND SOME OF THESE MAY DESCRIBE THE MOVEMENT OF EACH NUTRIENT THROUGH THE SYSTEM. FOR EXAMPLE, A SEPARATE EQUATION COULD BE WRITTEN TO DESCRIBE THE MOVEMENT OF PHOSPHORUS THROUGH A LAKE. THE EQUATIONS OF AN ECOSYSTEM MODEL ARE NORMALLY SOLVED FOR THE PURPOSE OF ESTIMATING THE MAGNITUDE, AND CHANGES IN THE MAGNITUDE, OF THE MODELED COMPONENTS. AS AN EXAMPLE, THE MODEL DEVELOPED FROM FIGURE 1 COULD BE USED TO PREDICT DAILY OR BIWEEKLY CHANGES IN PHOSPHORUS CONCENTRATION OR ALGAL BIOMASS.

UNFORTUNATELY, THERE ARE MAJOR PROBLEMS WHEN A MODEL IS APPLIED WITH THIS LEVEL OF COMPLEXITY. DESPITE THE FACT THAT MUCH IS KNOWN ABOUT THE AQUATIC ECOSYSTEM, MAN'S KNOWLEDGE MUST STILL BE CONSIDERED LIMITED AND THE MODEL REFLECTS ONLY A PORTION OF THAT LIMITED KNOWLEDGE. THEREFORE, A MODEL CANNOT BE EXPECTED TO MIMIC NATURE PRECISELY. IN ADDITION, THOUGH, AS A MODEL BECOMES MORE COMPLEX AND IS USED TO PROVIDE MORE DETAIL ABOUT THE SYSTEM OF STUDY, THE RATIO OF THAT WHICH IS UNKNOWN TO THAT WHICH IS KNOWN BECOMES LARGER, AND THE MODEL BECOMES LESS PRECISE. FOR EXAMPLE, AS A MODEL IS USED TO DESCRIBE SMALLER PERIODS OF TIME, RANDOM (UNEXPLAINED) EFFECTS BECOME MORE IMPORTANT TNA VICE VERSA. THUS, THE HIGH LEVEL OF DETAIL PRESENT IN AN ECOSYSTEM MODEL RESULTS IN ADDITIONAL UNCERTAINTY IN THE PREDICTIONS FROM THESE MODELS. THIS GENERALLY MEANS THAT ECOSYSTEM MODELS ARE OF ONLY LIMITED VALUE IN WATER QUALITY MANAGEMENT.

THE MOST USEFUL APPLICATION OF AN ECOSYSTEM MODEL IS PROBABLY AS A RESEARCH TOOL IN EXPANDING KNOWLEDGE OF THE AQUATIC ECOSYSTEM THROUGH THE TESTING OF VARIOUS HYPOTHESES. FOR EXAMPLE, A THEORY COULD BE ADVANCED ON THE INTERACTION BETWEEN DIFFERENT SPECIES OF PHYTOPLANKTON. THIS THEORY COULD THEN BE TRANSLATED INTO MATHEMATICAL EQUATIONS AND TESTED AS AN ECOSYSTEM MODEL. IF THE SIMULATION OF THIS INTERACTION BY THE MODEL YIELDS A SET OF RESULTS THAT ARE CONSISTENT WITH THE OBSERVED BEHAVIOR BETWEEN THESE SPECIES, THEN THIS TEST SUPPORTS THE THEORY. IF THE RESULTS ARE INCONSISTENT WITH OBSERVATION, THEN THE THEORY SHOULD PROBABLY BE RE-EXAMINED.

HOWEVER, AS SUGGESTED EARLIER, THE ECOSYSTEM MODEL DOES NOT REALIZE THE EXPRESSED NEED FOR A QUANTITATIVE TECHNIQUE FOR POLICY EVALUATION. THIS DOES NOT MEAN

THAT THE ECOSYSTEM MODEL IS NOT USEFUL FOR POLICY EVALUATION, BUT RATHER ITS USE IN LAKE MANAGEMENT IS PERHAPS ONE STEP REMOVED FROM THE DECISION-MAKERS. THAT IS, SINCE THE ECOSYSTEM MODELS MAY BE USEFUL IN TESTING SCIENTIFIC HYPOTHESES ABOUT THE AQUATIC ECOSYSTEM, THEY SHOULD INCREASE MAN'S UNDERSTANDING OF LIMNOLOGY. THIS CAN ONLY IMPROVE MAN'S ABILITY TO PLAN FOR LAKE MANAGEMENT.

THE EMPIRICAL PHOSPHORUS MODEL: DEVELOPMENT

FOR THE REASONS OF COST, SIMPLICITY, AND ERROR MENTIONED EARLIER, A SIMPLE LAKE MODEL IS AT PRESENT MORE USEFUL THAN THE ECOSYSTEM MODEL FOR THE EVALUATION OF SPECIFIC LAKE MANAGEMENT STRATEGIES. THIS SIMPLE MODEL IS OFTEN CALLED A "BLACK BOX" MODEL, AFTER THE MAGICIAN'S BLACK BOX. IT MAY BE REMEMBERED THAT THE MAGICIAN'S BLACK BOX HAS UNKNOWN CONTENTS, AND THE AUDIENCE SEES ONLY OBJECTS THAT ENTER THE BOX AND OBJECTS THAT EXIT THE BOX. THE BLACK BOX LAKE MODEL IS ANALAGOUS IN THAT THE MODELER IS CONCERNED ONLY WITH MATTER THAT ENTERS A LAKE AND MATTER THAT LEAVES THE LAKE. THE MODELER DOES NOT CONSIDER ANY OF THE BIOLOGICAL OR CHEMICAL REACTIONS OCCURRING WITHIN A LAKE. HOWEVER, AS A SUBSTITUTE FOR THESE REACTIONS, THE MODELER CREATES AN EMPIRICAL MODEL FROM THE BLACK BOX MODEL. THAT IS, THE MODELER EXAMINES DATA ON THE INPUTS AND OUTPUTS FOR MANY LAKES, AND THEN RELATES THE OUTPUTS TO THE INPUTS THROUGH A SIMPLE EQUATION DERIVED FROM THE DATA. IT MIGHT BE SAID THAT EMBODIED IN THIS EQUATION IS A SUMMARY OF THE COMBINED EFFECTS OF ALL OF THE CHEMICAL, BIOLOGICAL, AND PHYSICAL PROCESSES OCCURRING WITHIN A LAKE.

TABLE 1 CONTAINS A DERIVATION OF THE BLACK BOX PHOSPHORUS LAKE MODEL. THIS MODEL IS DEVELOPED FROM A "MASS BALANCE" ON PHOSPHORUS, WHICH IS SIMPLY THE SUMMATION OF ALL PHOSPHORUS INPUTS AND OUTPUTS (INCLUDING THE PHOSPHORUS SETTLING TO THE BOTTOM OF A LAKE) FOR A LAKE. THIS MASS BALANCE IS EXPRESSED IN EQUATION FORM, AND THEN THE EQUATION MAY BE SOLVED FOR THE LAKE PHOSPHORUS CONCENTRATION, P:

$$P = \frac{W}{v_S A + Q} \qquad (1)$$

WHERE:

P = PHOSPHORUS CONCENTRATION IN THE LAKE, IN PARTS PER MILLION (PPM), OR MILLIGRAMS PER LITER (MG/L)

W = TOTAL MASS (AMOUNT) OF PHOSPHORUS THAT ENTERS THE LAKE IN A YEAR, IN UNITS OF ONE MILLION GRAMS PER YEAR (10^6 G/YR)

v_S = APPARENT SETTLING VELOCITY OF PHOSPHORUS, IN METERS PER YEAR (M/YR)

A = LAKE SURFACE, OR BOTTOM, AREA, IN UNITS OF ONE MILLION SQUARE METERS (10^6 M^2)

Q = VOLUME OF WATER THAT FLOWS INTO, OR OUT OF, THE LAKE IN A YEAR, IN UNITS OF ONE MILLION CUBIC METERS PER YEAR ($10^6 M^3$/YR)

EQUATION 1 IS THE BLACK BOX PHOSPHORUS LAKE MODEL. IN ORDER TO USE THIS MODEL TO EVALUATE LAKE MANAGEMENT STRATEGIES, THE

The black box model for phosphorus may be derived from an inventory of phosphorus entering and leaving a lake. Mathematically, this inventory may be expressed as:

$$V\frac{DP}{DT} = W - v_S\ PA - QP \qquad \text{(T-I)}$$

where, for a one year period:

V = LAKE VOLUME, IN UNITS OF ONE MILLION CUBIC METERS $(10^6 M^3)$

P = PHOSPHORUS CONCENTRATION IN THE LAKE, IN PARTS PER MILLION (PPM), OR MILLIGRAMS PER LITER (MG/L)

W = TOTAL MASS (AMOUNT OF PHOSPHORUS THAT ENTERS THE LAKE IN A YEAR, IN UNITS OF ONE MILLION GRAMS PER YEAR $(10^6 G/YR)$

v_S = APPARENT SETTLING VELOCITY OF PHOSPHORUS, IN METERS PER YEAR (M/YR)

A = LAKE SURFACE, OR BOTTOM AREA, IN UNITS OF ONE MILLION SQUARE METERS $(10^6 M^2)$

Q = VOLUME OF WATER THAT FLOWS INTO, OR OUT OF, THE LAKE IN A YEAR, IN UNITS OF ONE MILLION CUBIC METERS PER YEAR $(10^6 M^3/YR)$

In words, this equation states that the change in the mass (amount) of phosphorus in a lake per unit time $(V\frac{DP}{DT})$ is equal to the mass of phosphorus that enters the lake from all sources (W), minus the mass of phosphorus that settles into the lake sediments $(V_S PA)$, minus the mass of phosphorus that leaves through the lake outlet (QP). Most applications of the black box model are based on the assumption that the phosphorus transport to and from the lake is in a "steady state". This means that, for the time period of interest (typically a year), the mass of phosphorus that enters a lake equals the mass of phosphorus that leaves the lake (through the outlet and into the sediments). In that case, the change in the mass of phosphorus in the lake is zero $(V\frac{DP}{DT} = 0)$, and Equation (T-I) becomes (after re-arranging):

$$W = v_S\ PA + QP \qquad \text{(T-2)}$$

Now, the variable of interest in Equation (T-2) is the steady-state phosphorus concentration (the phosphorus concentration that results if all other variables in Equation (T-2) are constant and do not change over time) in a lake (P). Therefore, Equation (T-2) will now be manipulated in order to solve for P:

$$P\ (v_S\ A + Q) = W \qquad \text{(T-3)}$$

OR

$$P = \frac{W}{v_S\ A + Q} \qquad \text{(T-4)}$$

Equation (T-4) is the phosphorus lake model.

TABLE 1

MODELER MUST DEVELOP AN EMPIRICAL ESTIMATE FOR v_s FROM A STATISTICAL STUDY OF LAKE DATA; ALL THE OTHER VARIABLES IN THE MODEL MAY BE ESTIMATED BY THE MODEL USER FOR THE APPLICATION LAKE. SO, FOR EXAMPLE, CHAPRA (1977) CONSTRUCTED AN EMPIRICAL MODEL FOR THE GREAT LAKES FROM EQUATION 1. CHAPRA EXAMINED A SET OF DATA AND FOUND THAT AN ESTIMATE OF $v_s = 16$ M/YR (FOR THE SETTLING OF PHOSPHORUS TO THE LAKE SEDIMENTS) RESULTED IN THE BEST MATCH BETWEEN PREDICTED AND OBSERVED PHOSPHORUS CONCENTRATION FOR THE LAKES STUDIED. THUS, CHAPRA'S EMPIRICAL PHOSPHORUS LAKE MODEL IS:

$$P = \frac{W}{16\,A + Q} \qquad (2)$$

IN A SIMILAR MANNER, OTHER INVESTIGATORS (VOLLENWEIDER AND DILLON, 1974; DILLON AND RIGLER, 1975; RECKHOW, 1978, 1979) HAVE STUDIED DATA ON LAKES AND CREATED DIFFERENT EMPIRICAL PHOSPHORUS LAKE MODELS FROM EQUATION 1.

THE EMPIRICAL PHOSPHORUS MODEL: APPLICATIONS

A DIAGRAM OF PHOSPHORUS MOVEMENT IN A LAKE AND LAKE WATERSHED MAY FACILITATE EXPLANATION OF THE USE OF THE PHOSPHORUS LAKE MODEL FOR LAKE MANAGEMENT. FIGURE 2 IS INTENDED TO ILLUSTRATE THAT LAND USES IN A LAKE WATERSHED RESULT IN THE MOVEMENT OF NUTRIENTS, LIKE PHOSPHORUS, TO A LAKE, REPRESENTED BY THE BOX. FIGURE 2 MAY BE TRANSLATED INTO A CONCEPTUAL MODEL, (SHOWING THE INTERACTIONS AMONG PHOSPHORUS-

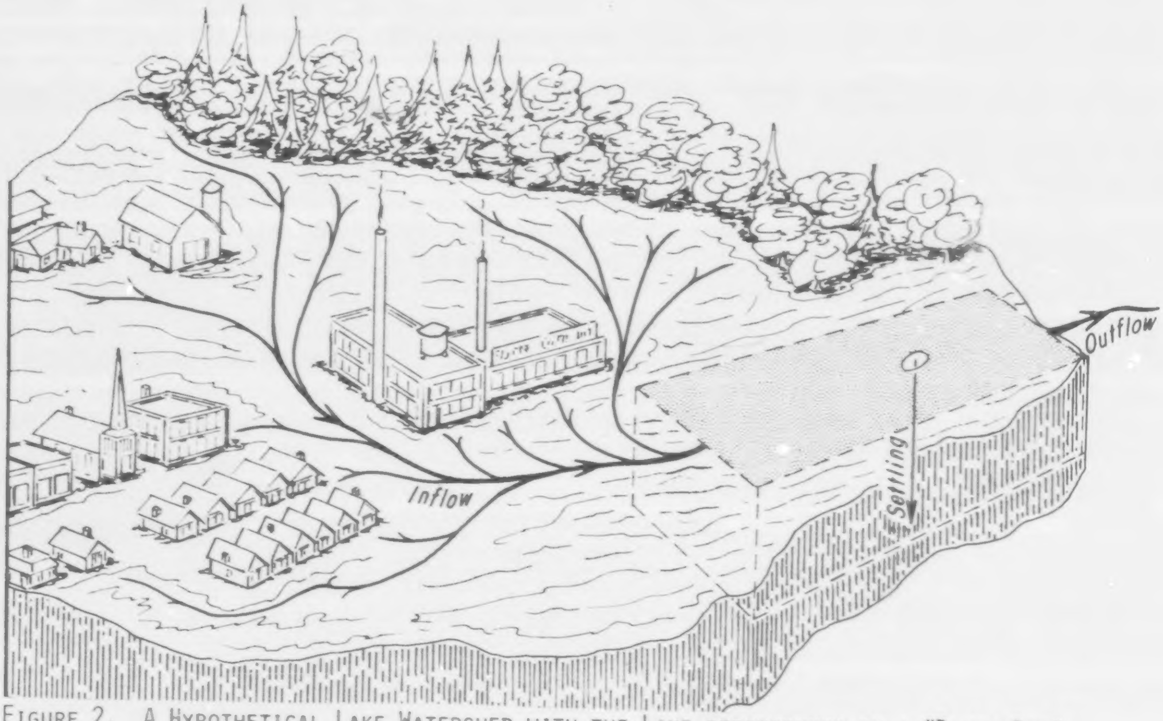

FIGURE 2. A HYPOTHETICAL LAKE WATERSHED WITH THE LAKE REPRESENTED BY A "BLACK BOX"

related factors in a lake and lake watershed) like that in Figure 3.

It is suggested in Figure 3 that the primary determinants of phosphorus input to a lake are climate, watershed characteristics (like soil type, bedrock, landslope, etc.), and human activities. Then, the relation between phosphorus input and phosphorus concentration in a lake is largely a function of lake morphometry (lake size and shape) and hydrology (e.g., the rate of water flow through a lake). Note that this "middle section" of the conceptual model in Figure 3 is equivalent to the black box phosphorus lake model in Equation 1. That is, the ratio between phosphorus input (W) and phosphorus concentration (P) in the model is the term: $v_s A + Q$. This term is simply composed of morphometric factor (A) and a hydrologic factor (Q), just as expressed in Figure 3. Finally, the conceptual model indicates why phosphorus is important in lake management by linking phosphorus concentration with chlorophyll a (a measure of the amount of plants and algae in a lake) and Secchi disk depth (a measure of water clarity).

Empirical phosphorus lake models have been used more often to evaluate lake management strategies than any other type of lake model. For example, the National Eutrophication Survey, conducted on about 800 lakes across the United States by the Environmental Protection Agency, applied phosphorus loading criteria developed by Vollenweider and Dillon (1974), to estimate the impact that changes in the phosphorus loading will have on the trophic state or pollution level for each of the 800 lakes. These loading criteria were

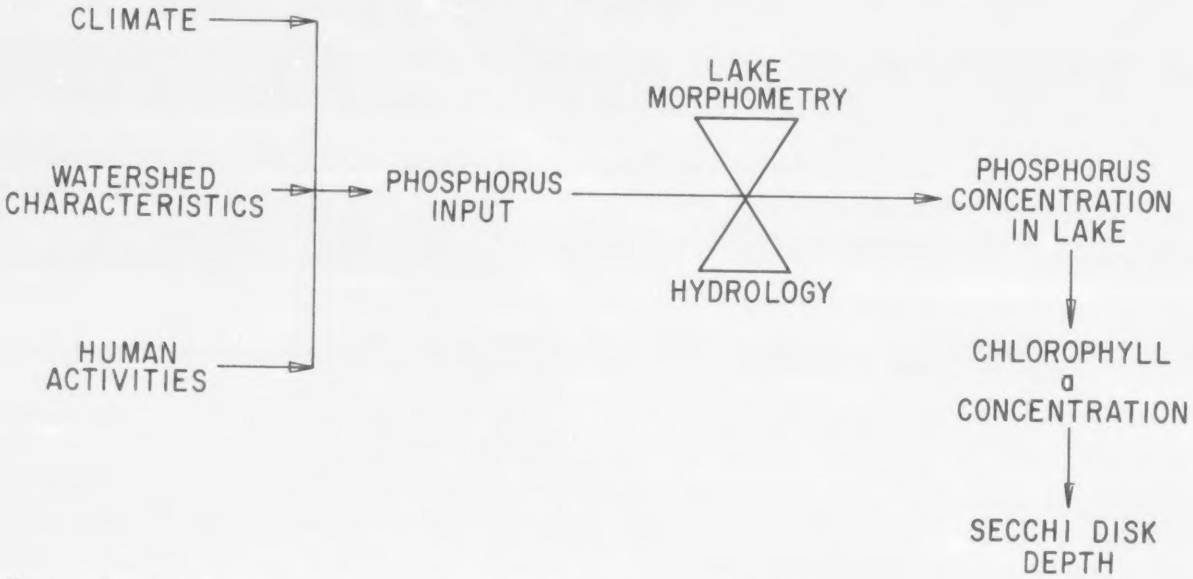
CLIMATE
WATERSHED CHARACTERISTICS
HUMAN ACTIVITIES
PHOSPHORUS INPUT
LAKE MORPHOMETRY
HYDROLOGY
PHOSPHORUS CONCENTRATION IN LAKE
CHLOROPHYLL a CONCENTRATION
SECCHI DISK DEPTH

Figure 3. A Conceptual Model of Phosphorus in a Lake and Lake Watershed

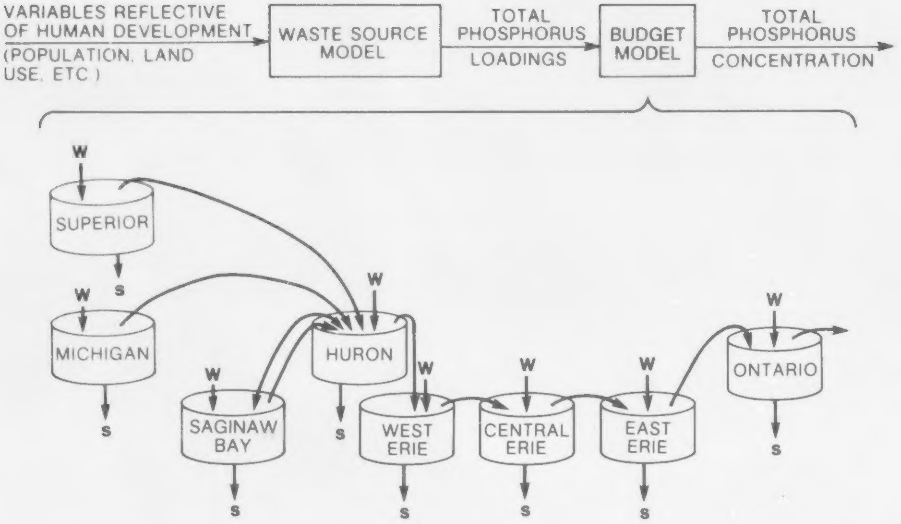
VARIABLES REFLECTIVE OF HUMAN DEVELOPMENT (POPULATION, LAND USE, ETC.)
WASTE SOURCE MODEL
TOTAL PHOSPHORUS LOADINGS
BUDGET MODEL
TOTAL PHOSPHORUS CONCENTRATION
W
SUPERIOR
S
MICHIGAN
SAGINAW BAY
HURON
WEST ERIE
CENTRAL ERIE
EAST ERIE
ONTARIO

Figure 4. Phosphorus Budget Model of Great Lakes (W Represents Waste Sources of Total Phosphorus from Lake's Drainage Basin; s Represents In-Lake Losses to Sediments; from Chapra, 1977)

developed from an empirical phosphorus model. In addition, Dillon and Rigler (1975), and more recently, Recknow (1978), have prepared manuals to guide the use of the empirical phosphorus model.

An interesting application of the empirical phosphorus model was presented by Chapra (1977). This involved quantification of the past, present, and projected future loadings of phosphorus to the Great Lakes, followed by prediction of the phosphorus concentration in the lakes, using the empirical phosphorus lake model. The remainder of this section is devoted to an examination of Chapra's work.

Figure 4 is a schematic representation of the complete Great Lakes model that Chapra used. Note that: the arrows represent the transport of phosphorus within the entire watershed; s represents the settling of phosphorus to the lake bottom, and Lake Erie is separated into three basins (due to quality differences among the basins). In addition, an assumption inherent in a black box model is that the lake is "completely mixed", such that the phosphorus concentration is assumed to be the same throughout the lake. Therefore, the model cannot be used to predict phosphorus levels in nearshore waters adjacent to major urban areas (where concentrations might be expected to be considerably higher than a complete lake average).

The model was first used to simulate the historical record, as a test of the model's validity. If this test could be accomplished successfully, then the model may be used for future projections with some confidence. Historical data on population and land use were used to generate the phosphorus loading to the Great Lakes, from 1800 to the present. Loadings were estimated for: domestic waste (which includes human waste and detergents); land

RUNOFF FROM AGRICULTURAL, URBAN, AND FORESTED LAND; AND ATMOSPHERIC SOURCES. IN ESTIMATING THE PHOSPHORUS LOADING, CHAPRA ASSUMED THAT: PHOSPHORUS LOADING FROM INDUSTRIAL SOURCES IS SMALL AND CAN BE NEGLECTED; AGRICULTURAL RUNOFF INCLUDES ALL AGRICULTURAL SOURCES (E.G., PESTICIDES, FERTILIZERS AND ANIMAL WASTE); LOADING ESTIMATES ARE NOT DEPENDENT UPON THE LOCATION OF THE SOURCE WITHIN THE WATERSHED. THIS FINAL ASSUMPTION CAN CAUSE SOME ERROR IN THE LOADING, BECAUSE A SOURCE OF PHOSPHORUS LOCATED ON THE LAKESHORE WILL CONTRIBUTE MORE PHOSPHORUS TO THE LAKE THAN THE SAME SOURCE LOCATED FAR BACK IN THE WATERSHED.

THE HISTORICAL PHOSPHORUS LOADINGS WERE CALCULATED FOR EACH CATEGORY BY MULTIPLYING WATERSHED POPULATION, OR WATERSHED AREA OCCUPIED BY EACH LAND USE CATEGORY, TIMES AN APPROPRIATE PHOSPHORUS "EXPORT FACTOR". THE EXPORT FACTOR IS AN ANNUAL PHOSPHORUS DISCHARGE, OBTAINED FROM OTHER STUDIES, THAT MAY BE USED TO QUANTIFY THE UNIT DISCHARGE FROM A CATEGORY (E.G., ANNUAL PHOSPHORUS DISCHARGE PER PERSON, OR ANNUAL PHOSPHORUS DISCHARGE PER ACRE OF FORESTED LAND). THUS, FOR RUNOFF FROM FORESTS:

$$W = A_D \; F_J \; (T) \; L_J \qquad (3)$$

EQUATION 3 STATES THAT THE TOTAL ANNUAL PHOSPHORUS EXPORT FROM FORESTED LAND (W) EQUALS THE AREA IN THE WATERSHED (A_D), TIMES THE FRACTION OF THAT AREA OCCUPIED BY FORESTS (F_J (T)), TIMES THE EXPORT FACTOR FOR FORESTS (L_J). THE D IN EQUATION 3 REFERS TO DRAINAGE (AREA), THE J REFERS TO TIME, AND INDICATES THAT THE FRACTION OF THE WATERSHED AREA OCCUPIED BY FORESTS CHANGES OVER TIME.

THE ESTIMATED PHOSPHORUS LOADINGS TO THE GREAT LAKES FOR THE PERIOD 1800-1970 ARE CALCULATED AS DESCRIBED ABOVE. THEY ARE THEN SUMMED, FOR EACH LAKE AND YEAR, FOR ALL PHOSPHORUS EXPORT CATEGORIES, TO DETERMINE THE TOTAL PHOSPHORUS LOADING TO EACH OF THE GREAT LAKES. FIGURE 5 IS A GRAPH OF THE CALCULATED HISTORICAL LOADINGS OF PHOSPHORUS (IDENTIFIED BY PHOSPHORUS SOURCES) TO THE FIVE LAKES. NOTE THE INCREASE DUE TO LAND RUNOFF BETWEEN 1850 AND 1900, AND THE INCREASE DUE TO DETERGENTS SINCE ABOUT 1940. USING THE EMPIRICAL PHOSPHORUS LAKE MODEL, THESE PHOSPHORUS LOADINGS MAY THEN BE CONVERTED TO PHOS-

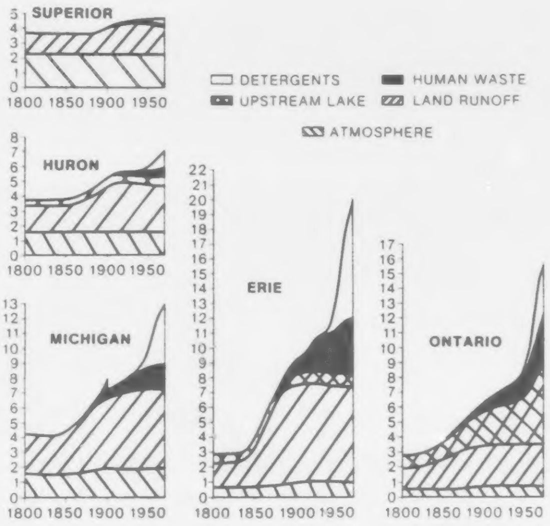

FIGURE 5. HISTORICAL LOADINGS OF TOTAL PHOSPHORUS, IN THOUSANDS OF TONS PER YEAR, AS CALCULATED BY MODEL (FROM CHAPRA, 1977)

phorus concentrations. The result is illustrated in Figure 6. Note, again, the two jumps in phosphorus levels (more apparent in the eastern lakes), and the higher concentrations of phosphorus in Lakes Erie (particularly the western basin) and Ontario. Chapra's work suggests that prior to the time of significant cultural influence (before 1800), the phosphorus concentrations in the Great Lakes were uniformly low. Conversion of forested land to agriculture in the late 1800's, coupled with increases in population and the introduction of phosphate detergents in the 1940's, have led to the present trophic conditions in the Great Lakes (according to the historical trends hypothesized in Figures 5 and 6).

To test the model, Chapra compared the measured phosphorus concentration in the Great Lakes with the predictions from the empirical phosphorus model. Agreement was fairly good, so future projections of phosphorus concentration were attempted using the model. Specifically, the model was used to answer the following question. How will the Lakes respond to reduced phosphorus loadings due to improved wastewater treatment which removes all of the phosphorus except one milligram per liter? In other words, the model was used to simulate what effect improved wastewater treatment (specifically, phosphorus removal)

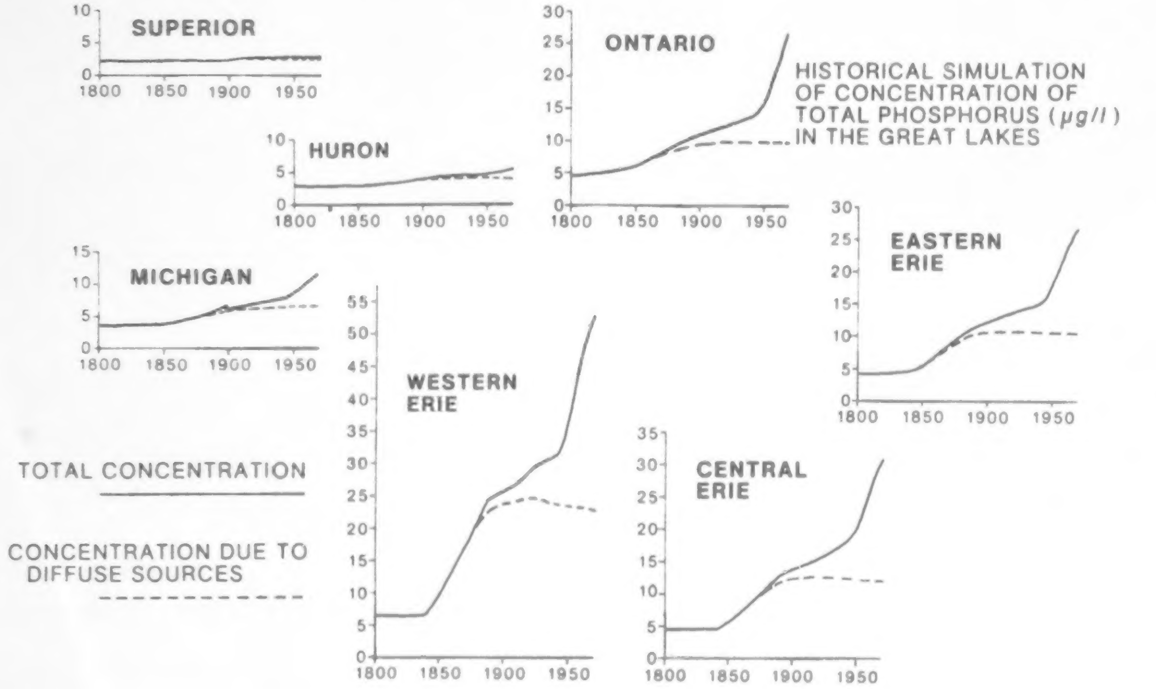

Figure 6. Historical Concentrations of Total Phosphorus, in micrograms per liter, as Calculated by Model (Dashed Line Represents Concentration due to Diffuse Sources; from Chapra, 1977)

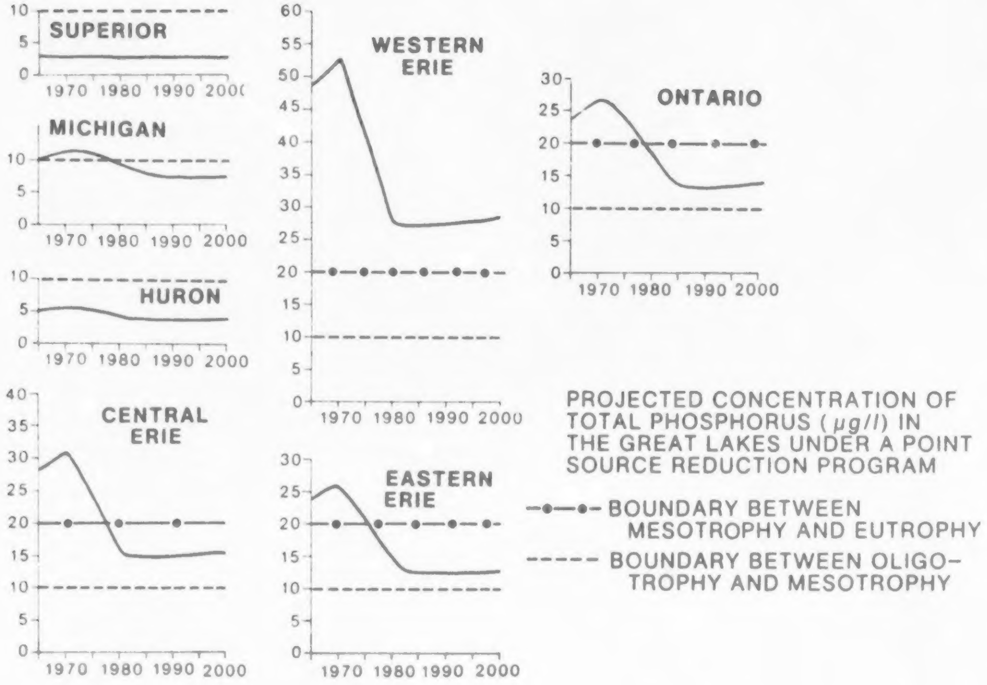

FIGURE 7. FUTURE SIMULATION OF CONCENTRATION OF TOTAL PHOSPHORUS, IN MICROGRAMS PER LITER, IN GREAT LAKES IN RESPONSE TO LINEAR DECREASE IN POINT SOURCE LOADINGS FROM 1970 VALUES TO ONE MG/L EFFLUENT IN 1980 (FROM CHAPRA, 1977)

WILL HAVE ON THE TROPHIC (POLLUTION) LEVEL OF THE LAKES DURING THE PERIOD, 1970-1980. ALL MUNICIPALITIES WOULD HAVE IMPROVED WASTEWATER TREATMENT BY 1980. IN ADDITION, POPULATION INCREASES WERE PROJECTED, BUT ALL OTHER LAND USE CATEGORIES AND PHOSPHORUS EXPORTS WERE ASSUMED TO REMAIN AT THE 1970 LEVEL.

THE RESULTS OF THIS EXERCISE ARE PRESENTED IN FIGURE 7. THE DASHED LINES ON THE FIGURE CORRESPOND TO THE TRANSITIONS BETWEEN THE TROPHIC STATES. EUTROPHY SIGNIFIES A NUTRIENT-RICH STATE; OLIGOTROPHY REPRESENTS A NUTRIENT-POOR CONDITION; AND MESOTROPHY IS THE INBETWEEN STATE. THE MODEL PREDICTIONS SUGGEST THAT THIS HYPOTHETICAL MANAGEMENT STRATEGY WOULD HAVE MORE IMPACT ON THE EASTERN LAKES, AND IT WOULD BE EXPECTED TO RESULT IN A CHANGE OF TROPHIC STATE FOR LAKES MICHIGAN, ONTARIO, CENTRAL ERIE, AND EASTERN ERIE. HOWEVER, WESTERN ERIE WOULD BE EXPECTED TO REMAIN EUTROPHIC. THE REASON FOR THIS RESPONSE BY WESTERN ERIE IS SUGGESTED BY FIGURES 5 AND 6. MUCH OF THE PHOSPHORUS ENTERING THE WESTERN BASIN OF LAKE ERIE IS APPARENTLY FROM LAND RUNOFF, AND, THEREFORE, IT IS NOT AFFECTED BY CONTROLS ON WASTEWATER TREATMENT PLANTS.

IN ANOTHER PAPER, CHAPRA AND ROBERTSON

(1977) EXAMINED THE IMPACT OF OTHER MANAGEMENT STRATEGIES ON THE GREAT LAKES, AND ON GREEN BAY AND SAGINAW BAY. USING THE EMPIRICAL PHOSPHORUS LAKE MODEL AND PRESENT CONDITIONS, THEY PREDICTED THAT THE ACHIEVEMENT OF THE UNITED STATES GOAL (AS EXPRESSED IN THE 1972 FEDERAL WATER POLLUTION CONTROL ACT AMENDMENTS) OF "NO DISCHARGE" OF WASTES INTO SURFACE WATER BODIES, AND THE ELIMINATION OF ALL AGRICULTURAL RUNOFF, WOULD BE NEEDED TO RETURN WESTERN LAKE ERIE TO ITS NATURAL OLIGOTROPHIC STATE. FURTHER, IN FIGURE 8, CHAPRA AND ROBERTSON ALLOCATED THE TOTAL PHOSPHORUS CONCENTRATION PREDICTED FOR EACH OF THE WATER BODIES AMONG THE PHOSPHORUS SOURCES, ACCORDING TO THE RELATIVE CONTRIBUTION FROM THESE SOURCES. IT IS SUGGESTED IN THIS FIGURE THAT GREEN BAY AND SAGINAW BAY WERE NOT NATURALLY OLIGOTROPHIC. THIS IS INTERESTING, BECAUSE IT IS GENERALLY THOUGHT THAT MOST LARGE, DEEP LAKES ARE NATURALLY OLIGOTROPHIC. THESE BAYS, HOWEVER, ARE RELATIVELY SHALLOW, WITH LARGE DRAINAGE BASINS, AND THUS COULD BE NATURALLY MESOTROPHIC. ANOTHER INTERESTING RESULT OF THE ANALYSIS LEADING TO FIGURES 7 AND 8 IS THE DIFFERENCE BETWEEN A ONE MILLIGRAM PER LITER (MG/L) MAXIMUM DISCHARGE FOR

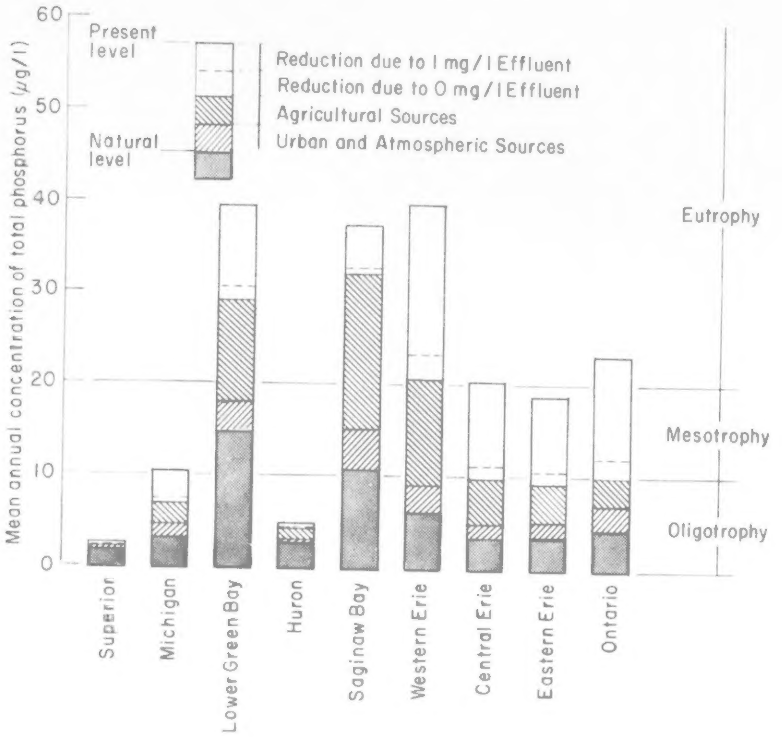

FIGURE 8. TOTAL PHOSPHORUS CONCENTRATIONS RESULTING FROM VARIOUS TREATMENT SCHEMES FOR THE GREAT LAKES (FROM CHAPRA AND ROBERTSON, 1977)

PHOSPHORUS (FOR WASTEWATER TREATMENT PLANTS) AND NO DISCHARGE. THE ONE MG/L REQUIREMENT CAN GENERALLY BE MET, BY A DISCHARGER, WITH THE ADDITION OF A PHOSPHATE REMOVAL PROCESS. ZERO DISCHARGE, HOWEVER, PROBABLY REQUIRES LAND TREATMENT OF WASTEWATER (E.G. WASTEWATER IRRIGATION OF FORESTS OR AGRICULTURAL FIELDS) AND FOR MANY DISCHARGERS THIS COULD BE QUITE COSTLY. THE DIFFERENCE, THEREFORE, BETWEEN THESE TWO STRATEGIES COULD BE SUBSTANTIAL IN TERMS OF COST. IN CONTRAST, THE ANALYSIS PRESENTED IN FIGURE 8 IMPLIES THAT THE DIFFERENCE IN THE RESULTANT PHOSPHORUS CONCENTRATION (ASSOCIATED WITH THESE TWO STRATEGIES) IN THE GREAT LAKES MAY BE SO SMALL THAT THE SLIGHT IMPROVEMENT IN TROPHIC STATE MAY NOT JUSTIFY THIS COST.

CONCLUSIONS ON MANAGEMENT ISSUES, LIKE THAT STATED ABOVE, ARE A MAJOR GOAL OF THE APPLICATION OF AN EMPIRICAL PHOSPHORUS LAKE MODEL. HOWEVER, NOTHING HAS BEEN SAID ABOUT THE CONFIDENCE THE MODELER, OR THE PLANNER, SHOULD HAVE IN THE RESULT. THE LIMITATIONS ON THE USE OF THE MODEL, AND THE PRECISION, OR UNCERTAINTY, OF A MODEL PREDICTION ARE IMPORTANT ISSUES AND ARE THE FOCUS OF THE NEXT SECTION.

THE EMPIRICAL PHOSPHORUS MODEL: UNCERTAINTY AND LIMITATIONS

IN THE FIRST SECTION OF THIS PAPER IT WAS NOTED THAT A MATHEMATICAL MODEL IS A SIMPLIFIED REPRESENTATION OF A REAL SYSTEM. THIS SIMPLICITY IMPLIES THAT THE PREDICTIONS FROM A MODEL CANNOT BE PRECISE. FURTHER, A MODEL, LIKE THE EMPIRICAL PHOSPHORUS LAKE MODEL, REQUIRES ESTIMATES OF CERTAIN QUANTITIES (E.G., PHOSPHORUS LOADING) FOR APPLICATION OF THE MODEL. THE ESTIMATES OF THESE TERMS CAN OFTEN BE UNCERTAIN. FOR EXAMPLE, IN ORDER TO ESTIMATE THE ANNUAL PHOSPHORUS LOADING TO A LAKE WITH CERTAINTY, EVERY SOURCE OF PHOSPHORUS MUST BE MONITORED CONTINUOUSLY FOR THE ENTIRE YEAR. THIS IS OBVIOUSLY IMPOSSIBLE, AND THUS, ALL MEASURED PHOSPHORUS LOADINGS ARE UNCERTAIN. FURTHERMORE, WHEN THE PHOSPHORUS LOADING IS NOT MEASURED, BUT RATHER TAKEN FROM MEASURED VALUES REPORTED IN OTHER STUDIES, IT BECOMES MORE UNCERTAIN.

IT IS APPARENT THAT AN ESTIMATE OF THE TOTAL UNCERTAINTY ASSOCIATED WITH A PREDICTION IS NEEDED. THE TOTAL UNCERTAINTY DEFINES THE PRECISION OF A PREDICTION, AND IT ALSO MAY BE USED AS A WEIGHT REFLECTING THE INFORMATION CONTENT OF THE PREDICTION. IF THE UNCERTAINTY IS SMALL, THE PREDICTION IS MORE PRECISE, AND THE USER OF THE MODEL SHOULD ASSIGN CONSIDERABLE WEIGHT TO THE PREDICTION AS INFORMATION FOR THE LAKE MANAGEMENT PROCESS. IF, ON THE OTHER HAND, THE UNCERTAINTY IS LARGE, THEN THE PREDICTION IS LESS PRECISE, AND THE MODEL USER SHOULD WEIGH OTHER SOURCES OF INFORMATION MORE HEAVILY RELATIVE TO THE MODEL PREDICTION. TECHNIQUES HAVE BEEN PROPOSED (RECKHOW, 1978) THAT MAY BE USED TO QUANTIFY THE UNCERTAINTY ASSOCIATED WITH EACH OF THE MODEL TERMS AND THEN COMBINE THESE UNCERTAINTY CONTRIBUTIONS FOR AN ESTIMATE OF

THE PREDICTION UNCERTAINTY FOR THE EMPIRICAL PHOSPHORUS LAKE MODEL. HOWEVER, WHETHER THE PREDICTION UNCERTAINTY IS LARGE OR SMALL, IT MUST ALWAYS BE REMEMBERED THAT THE MODEL IS JUST ONE TECHNIQUE THAT MAY BE USEFUL IN LAKE MANAGEMENT.

THE POTENTIAL MODEL USER MUST ALSO BE AWARE THAT THERE ARE LIMITATIONS ON THE USE OF THE EMPIRICAL PHOSPHORUS LAKE MODEL. THESE LIMITATIONS GENERALLY RESULT FROM THE FACT THAT THE MODEL IS DEVELOPED FROM THE ASSUMPTION THAT A LAKE IS A COMPLETELY-MIXED BLACK BOX. THIS MEANS THAT:

1. DUE TO ITS BLACK BOX NATURE, THE MODEL DOES NOT EXPLICITLY INCLUDE ANY BIOLOGICAL COMPONENTS, NOR DOES IT INCLUDE ANY OTHER NUTRIENTS BESIDES PHOSPHORUS. THEREFORE, LAKES WITH UNUSUAL CHARACTERISTICS RELATED TO THESE UNMODELED VARIABLES PROBABLY WILL NOT BE MODELED WELL.
2. THE EMPIRICAL PHOSPHORUS LAKE MODEL IS AGGREGATED IN TIME AND SPACE. IT IS AGGREGATED IN TIME SINCE IT IS NORMALLY USED TO PREDICT YEARLY AVERAGE VALUES, AND THUS IT CANNOT BE USED (AS DEVELOPED HEREIN) TO PREDICT PHOSPHORUS CONCENTRATION FOR A TIME PERIOD OF LESS THAN A YEAR. THE MODEL IS AGGREGATED IN SPACE SINCE IT IS USED TO PREDICT THE AVERAGE CONCENTRATION FOR AN ENTIRE LAKE, AND THUS IT CANNOT BE USED TO PREDICT VARIATIONS IN CONCENTRATION WITHIN A LAKE.

   IN SUMMARY, APPLICATION OF THE MODEL WILL YIELD AN AVERAGE PHOSPHORUS CONCENTRATION, AVERAGED OVER THE ENTIRE YEAR AND THROUGHOUT A LAKE.

ONE FINAL IMPORTANT LIMITATION ON THE USE OF THE EMPIRICAL PHOSPHORUS LAKE MODEL RESULTS FROM THE MODEL'S EMPIRICAL NATURE.

3. THE EMPIRICAL MODEL (EQUATION 2) WAS DEVELOPED FROM DATA ON LAKES LOCATED IN THE NORTH TEMPERATE CLIMATIC ZONE. SINCE CLIMATE AFFECTS THE TEMPERATURE OF A LAKE AND THE GROWTH OF PLANTS AND ALGAE WITHIN A LAKE, CLIMATE WILL ALSO AFFECT THE RELATION BETWEEN PHOSPHORUS INPUTS AND OUTPUTS DEFINED IN THE EMPIRICAL PHOSPHORUS LAKE MODEL. THIS CAN DIMINISH THE ACCURACY OF THE MODEL. THUS, AN EMPIRICAL MODEL DEVELOPED USING DATA FROM THE NORTH TEMPERATE REGION SHOULD NOT BE APPLIED TO LAKES IN A DIFFERENT CLIMATIC ZONE UNLESS THE MODEL HAS BEEN SUCCESSFULLY TESTED IN THAT NEW ZONE.

THE THREE ITEMS LISTED ABOVE REPRESENT THE MAJOR LIMITATIONS ON THE EMPIRICAL PHOSPHORUS LAKE MODEL. IN A MORE GENERAL SENSE, LIMITATIONS EXIST ON THE USE OF A MODEL BECAUSE MODELS OFTEN REFLECT CERTAIN UNDERLYING CONDITIONS (LIKE CLIMATE) IN A SYSTEM. SOME MODELS MAY NOT BE ADAPTABLE TO CHANGES IN THESE CONDITIONS.

THEREFORE, THE SKILL OF A MODEL USER IS REQUIRED FOR AN ASSESSMENT OF THE ADAPTABILITY OF A MODEL AND FOR THE SELECTION OF AN ALTERNATIVE MODEL IF NECESSARY.

CONCLUSIONS

THIS PAPER IS INTENDED TO SERVE AS AN INTRODUCTION TO MATHEMATICAL MODELS OF LAKES. TWO DIFFERENT TYPES OF MODELS WERE DESCRIBED HEREIN: THE COMPLEX AQUATIC ECOSYSTEM MODEL AND THE SIMPLE EMPIRICAL PHOSPHORUS LAKE MODEL. AFTER REASONS WERE PRESENTED FOR FAVORING THE EMPIRICAL PHOSPHORUS LAKE MODEL AS A TECHNIQUE FOR THE EVALUATION OF LAKE MANAGEMENT STRATEGIES, THIS MODEL WAS USED TO EVALUATE POLICY FOR THE GREAT LAKES. FINALLY, THE IMPORTANCE OF UNCERTAINTY AND THE MAJOR LIMITATIONS ON THE USE OF THE EMPIRICAL PHOSPHORUS LAKE MODEL WERE DISCUSSED.

IT WAS SUGGESTED IN THE INTRODUCTION THAT DIFFERENT TYPES OF LAKE MODELS ARE DEVELOPED FOR DIFFERENT PURPOSES. THE EMPIRICAL PHOSPHORUS MODELS DISCUSSED HEREIN MAY PROVE MOST USEFUL IN 1) SUGGESTING GENERAL TRENDS IN LAKE QUALITY (CHAPRA, 1977); 2) PROVIDING A QUICK ASSESSMENT OF QUALITY AND AN INITIAL ATTEMPT TO DETERMINE PHOSPHORUS "CARRYING CAPACITY" FOR A NUMBER OF LAKES (RECKHOW, 1978; AND 3) INTRODUCING USEFUL QUANTITATIVE TECHNIQUES TO PLANNERS AND DECISION MAKERS IN LAKE MANAGEMENT WHO HAVE NOT PREVIOUSLY USED MATHEMATICAL MODELS. SINCE THESE MODELS CAN BE USED BY THOSE UNFAMILIAR WITH THE THEORY AND ASSUMPTIONS BEHIND THE TECHNIQUES, IT IS CRITICALLY IMPORTANT THAT THE LIMITATIONS ON THE USE BE CLEARLY DOCUMENTED; THIS WAS DONE IN THE LAST SECTION OF THIS PAPER. IT MUST BE REMEMBERED THAT THE MODEL OUTPUT CAN ONLY BE AS GOOD AS THE INPUT DATA AND AS APPLICABLE AS THE MODEL ASSUMPTIONS. FOR EXAMPLE, BECAUSE THE EMPIRICAL PHOSPHORUS LAKE MODEL WAS DEVELOPED TO PREDICT THE ANNUAL AVERAGE LAKEWIDE PHOSPHORUS CONCENTRATION, THIS MODEL CANNOT BE USED TO EVALUATE NEARSHORE OR SEASONAL EFFECTS. YET WITH ACCURATE INPUT DATA, EMPIRICAL PHOSPHORUS LAKE MODELS CAN PROVIDE A GOOD INDICATION OF AVERAGE (IN TIME AND SPACE) LAKE QUALITY CONDITIONS.

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POLITICAL PROCESS AND APPLICATIONS

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WATER QUALITY LAWS:

THAT AN ENVIRONMENTAL CRISIS EXISTS IS A PROPOSITION WHICH IS WELL DOCUMENTED. ONE MIGHT GLIBLY INDICATE THAT THE "FACTS ARE IN" CONCERNING MAN'S HARM TO THE ENVIRONMENT, BUT OBVIOUSLY, ALL THE FACTS ARE NOT IN. INDEED, EACH DAY'S NEWSPAPER BRINGS ADDITIONAL EVIDENCE OF THE ACTUAL INTENSITY OF THE CRISIS ITSELF. NO LONGER IS IT MERELY THE MATTER OF A RALPH NADER OR A BARRY COMMONER CRYING IN THE WIND. EVEN THE MOST STOIC MUST NOW ADMIT THAT THE CONSEQUENCES OF ENVIRONMENTAL MISMANAGEMENT ARE GREATER THAN THE LOSS OF THE ROBIN OR THE EAGLE. IT IS MAN HIMSELF THAT FACES A CRISIS FOR SURVIVAL. THE DAILY IMPAIRMENT OF THE CLIMATIC, AQUATIC, EDAPHIC, BIOTIC, SOCIAL AND AESTHETIC ELEMENTS OF THE GREAT LAKES BASIN IS A CAUSE FOR INCREASING CONCERN. HOPEFULLY, MANKIND HAS ENOUGH LEAD-TIME THAT HE MAY NOW MAKE THOSE PRUDENT JUDGMENTS WHICH WILL MITIGATE THESE "CRISES." HOWEVER, THERE IS THE OMNIPRESENT FOREBODING THAT SOME OF THE DECISIONS WHICH HAVE BEEN MADE ARE ALREADY IRREVERSIBLE. IN ANY EVENT, SOLUTIONS (NOT MERE AWARENESS) ARE THE RELEVANT ISSUES. THEREFORE, TO ENUMERATE VARIOUS CATASTROPHIES IN THE ENVIRONMENT WOULD BELABOR THE POINT.

THE AVAILABLE NATURAL RESOURCES BASE IS BECOMING MORE LIMITED AT THE SAME TIME THAT HUMAN POPULATION IS EXPERIENCING A PERIOD OF EXPLOSIVE GROWTH. AS THOMAS MALTHUS HAS INDICATED, "THE POWER OF POPULATION IS INFINITELY GREATER THAN THE POWER IN THE EARTH TO PRODUCE SUBSISTENCE FOR MAN." IN THE ABSENCE OF RE-CYCLING PROCESSES, THIS PROBLEM EVEN EXTENDS TO RENEWABLE RESOURCES. THEREFORE, CONFLICTS WITH RESPECT TO ACCESS TO THESE LIMITED RESOURCES AND CONFLICTS CONCERNING RESOURCE MANAGEMENT AND THE DISPOSAL OF WASTES PRODUCED BY RESOURCE CONSUMPTION APPEAR INEVITABLE.

THE AMERICAN LEGAL SYSTEM IS THE MECHANISM EMPLOYED BY OUR SOCIETY TO RESOLVE THESE CONFLICTS. THIS MECHANISM ACTUALLY REPRESENTS TWO SYSTEMS. THE FORMAL LEGAL SYSTEM IS ILLUSTRATED BY THE CLASSIC SOURCES OF LEGAL PRINCIPLES: COURTS AND CASES; LEGISLATURES AND STATUTES; AND EXECUTIVE AGENCIES AND ADMINISTRATIVE REGULATIONS. THE EQUALLY LEGITIMATE, INFORMAL LEGAL SYSTEM INCLUDES CUSTOMS; THE COMPLIANCE-DEVIANCE SPECTRUM; AND A BROAD RANGE OF CONDUCT PATTERNS THAT MAKE ADMINISTRATION OF WATER QUALITY PROGRAMS POSSIBLE. THE INFORMAL SYSTEM IS FREQUENTLY DESCRIBED AS "LAW-IN-ACTION". THUS, THE PRINCIPLES OF WATER POLLUTION LAW ARE NOT LIMITED TO A STATIC SET OF RULES WHICH CLEARLY DECIDE EACH RESOURCE CONFLICT. IMPLEMENTATION OF THE "RULES" REQUIRES AN APPROPRIATE BALANCE BETWEEN TECHNOLOGY AND FLEXIBLE, CONFLICT-RESOLUTION MECHANISMS. AN UNDERSTANDING OF ANY AREA OF LAW REQUIRES

MORE THAN AN ATTEMPT TO ISOLATE SELECTED LEGAL DOCTRINES AND TO APPLY THEM TO A SOCIAL OR POLITICAL PROBLEM. THIS MEANS THAT WATER POLLUTION LAW IS MORE THAN THE "LEGAL ASPECTS" OF WATER QUALITY. IN SHORT, THE WELL-SEASONED WISDOM OF MAX RADIN WARNS: "THOSE OF US WHO HAVE LEARNED HUMILITY HAVE GIVEN OVER THE ATTEMPT TO DEFINE LAW."

WATER POLLUTION ABATEMENT LAWS HAVE BEEN INCORPORATED INTO A NEW NOMENCLATURE, "ENVIRONMENTAL LAW". IN THE NEW AND EMERGING FIELD OF ENVIRONMENTAL LAW THERE ARE ESSENTIALLY THREE LEVELS OF ANALYSIS. EACH LEVEL IS REPRESENTED BY A DIFFERENT GROUP OF INDIVIDUALS. IN THE FIRST GROUP, ONE FINDS THE LAY CONSERVATION ORGANIZATIONS -- PERHAPS WELL-MEANING, BUT OFTEN WITHOUT AN ADEQUATE BASE OF CONCRETE KNOWLEDGE. THIS SAME GROUP PROVIDES AN UMBRELLA FOR THE PSEUDO-ECOLOGIST WHO PRODUCES THE CRIES OF WOE AND WHAT ARE PROPERLY CALLED "IMAGINARY HORRIBLES". IN THE SECOND GROUP, ONE DISCOVERS SCIENTISTS WHO ARE PROGRESSIVELY AND METHODICALLY PRODUCING CONCRETE PHYSICAL SOLUTIONS TO SPECIFIC ENVIRONMENTAL PROBLEMS. THE THIRD GROUP OF INDIVIDUALS IN THE AREA OF ENVIRONMENTAL LAW INCLUDES PRACTICING ATTORNEYS AND OTHERS AFFILIATED WITH THE LEGAL PROFESSION.

A CRUCIAL PROBLEM IN ENVIRONMENTAL LAW IS THE LACK OF COMMUNICATION BETWEEN SCIENTISTS AND THE LEGAL SYSTEM. IN GENERAL, SCIENTISTS ARE FAR AHEAD OF THE LAW IN FINDING ANSWERS TO ENVIRONMENTAL PROBLEMS BUT ARE UNABLE TO IMPLEMENT THEIR SOLUTIONS WITHOUT ADEQUATE LEGAL MECHANISMS. MANY OF THE APPLICABLE LEGAL SOLUTIONS OR REMEDIES TO CURRENT ENVIRONMENTAL ISSUES HAVE NOT CHANGED IN ANY SIGNIFICANT MANNER FOR MANY CENTURIES. FOR EXAMPLE, THE TRADITIONAL REMEDIES OF NUISANCE AND TRESPASS LITIGATION HAVE PROVEN INADEQUATE TO CURB POLLUTION. PRESCRIPTION FREQUENTLY ALLOWS "VESTED PROPERTY INTERESTS" TO CONTINUE TO CONDUCT PATTERNS WHICH DEGRADE THE QUALITY OF LIVING. THESE "INTERESTS" MAY RANGE FROM THE INDIVIDUAL PROPERTY OWNER THROUGH THE FEED-LOT OPERATOR TO THE LARGE INDUSTRIAL COMPLEX. MOREOVER, AS ILLUSTRATED BELOW, THE CONTRIBUTIONS OF NEARLY EVERY AREA OF HUMAN KNOWLEDGE BECOME RELEVANT TO THE IMPROVEMENT OF THE QUALITY (USE AND ENJOYMENT) OF WATER IN THE GREAT LAKES BASIN. FOR EXAMPLE, THE ECONOMIST (COSTS VS. BENEFITS), THE POLITICAL SCIENTIST OR SOCIOLOGIST (EFFECTIVE PUBLIC INVOLVEMENT), OR THE HISTORIAN (PRESERVATION OF CULTURAL HERITAGE), ETC. ALL HAVE CONTRIBUTIONS.

EVER SO SLOWLY, THE LAW CHANGES TO MEET NEW SOCIAL NEEDS. FOR EXAMPLE, MICHIGAN HAS RECENTLY PASSED THE ENVIRONMENTAL PROTECTION ACT OF 1970. THIS LAW, PUBLIC ACT 127 OF THE PUBLIC ACTS OF 1970, ALLOWS CITIZENS TO SUE THOSE IMPAIRING THE NATURAL RESOURCES OF MICHIGAN. EVEN IN THE ABSENCE OF THIS FORM OF ENABLING LEGISLATION, NEW "CLASS ACTIONS" (WITHIN THE SCOPE OF EQUITY JURISDICTION) HAVE BEEN DEVELOPED. HOWEVER, LESS THAN TEN YEARS AGO, BEFORE THESE NEW REMEDIES WERE RECOGNIZED, THE TRADITIONAL PLAINTIFF DID NOT HAVE "STANDING TO SUE" UNLESS HE COULD DEMONSTRATE A PERSONAL PECUNIARY LOSS FROM THE ALLEGED IMPAIRMENT OF THE ENVIRONMENT. HIS ONLY RECOURSE WAS TO FILE A COMPLAINT WITH THE APPROPRIATE ADMINISTRATIVE AGENCY. THE AGENCY--STAFFED BY A GROUP OF TECHNICAL EXPERTS AND

AUTHORIZED TO PROTECT THE "PUBLIC INTEREST" BY REGULATING A PARTICULAR FORM OF CONDUCT OR A SPECIFIC INDUSTRY--FREQUENTLY HAD ALREADY BEEN "CAPTURED" BY THOSE SUBJECT TO THE REGULATIONS.

PROFESSOR SAX (1971) HAS ATTEMPTED TO DEFINE "ENVIRONMENTAL LAW" AS FOLLOWS:

> AN ENVIRONMENTAL LAW PROBLEM IS PRESENTED WHEN THERE IS A LOSS OF EFFECTIVE CONTROL OVER THE IMPACT OF HUMAN ACTIVITY ON NATURAL COMMUNITIES. AND THE JOB OF THE ENVIRONMENTAL LAWYER IS TO RESTORE THAT CONTROL. THE KEY WORD IN THIS FORMULATION IS CONTROL.
>
> PROBABLY THE BEST KNOWN EXAMPLE OF SUCH A PHENOMENON IS THE BUILD-UP OF PESTICIDES IN SPECIES OTHER THAN THE TARGET ORGANISMS. THIS BUILD-UP IN MAN AND BIRDS FOR EXAMPLE, IS UNCONTROLLED IN SEVERAL RESPECTS. IT DEVELOPS AT A RATE AND IN A MANNER THAT IS NOT INTENDED OR DESIRED, AND WITH CONSEQUENCES THAT ARE NOT WELL UNDERSTOOD; IN THIS SENSE THE USE OF THE PESTICIDE IS UNCONTROLLED. HOW ABOUT HARMFULNESS? MUST IT ALSO BE PROVEN HARMFUL TO MEET MY TEST OF BEING UNCONTROLLED? THE ANSWER IS NO: FOR WHAT YOU DO NOT KNOW, YOU DO NOT CONTROL.

THIS, OF COURSE, IS ONE RESPONSE, ONE ATTEMPT TO REVIEW THE LEGAL TOOLS WHICH HAVE SOME POTENTIAL FOR THE CONTROL OF WATER QUALITY PROBLEMS ON THE GREAT LAKES.

COMPLEXITIES

THE "LEGAL ASPECTS" OF THE CONTROL OF THE QUALITY OF WATER IS A VERY COMPLEX SET OF INTERDISCIPLINARY AND MULTI-DISCIPLINARY ISSUES. THE MOST CRITICAL QUESTION THAT THE STUDENT IN THIS FIELD OF STUDY MUST ASK IS QUALITY FOR WHAT PURPOSE. THESE "ASPECTS" INCLUDE RULES OF CONDUCT FOR WATER POLLUTION, WATER CONTAMINATION, REASONABLE USE, AND MUCH MORE. IN A WORD, "POLLUTION" IS RELATIVE TO THE PURPOSE OR OBJECTIVES SELECTED BY THE REGULATOR OR CLAIMANT.

THE LEADING TREATISE WRITER HAS SUGGESTED: "WATER QUALITY" IS A RELATIVE THING, FOR IT MUST ALWAYS BE CONSIDERED WITH REFERENCE TO A SPECIFIC USE. THE TEST OF WHETHER WATER QUALITY IS GOOD OR BAD IS NOT ITS PURITY IN ANY ABSOLUTE SENSE BUT RATHER ITS USEFULNESS FOR SOME SPECIFIC PURPOSE. FOR EXAMPLE, DISTILLED WATER, WHICH IS FREE FROM ALL IMPURITIES, IS REQUIRED FOR AN AUTOMOBILE BATTERY CELL, BUT IT HAS A FLAT AND UNPALATABLE TASTE; AND THE VERY MINERALS WHICH MAKE DRINKING WATER PALATABLE WILL RUIN A BATTERY. THE SAME WATER WILL BE OF GOOD QUALITY FOR ONE PURPOSE, BUT OF BAD QUALITY FOR THE OTHER. IN A SIMILAR VEIN, NATURAL SEAWATER IS USELESS--INDEED HARMFUL--IN A BATTERY OR AS DRINKING WATER; FOR THESE PURPOSES IT IS OF BAD OR LOW QUALITY, EVEN THOUGH IT HAS NOT BEEN POLLUTED BY MAN. TO RAISE THE QUALITY OF SEAWATER, DESALINATION IS REQUIRED.

EUTROPHICATION OF THE GREAT LAKES BY BOTH HUMAN AND NATURAL AGENCIES IS ANOTHER EXAMPLE OF THE RELATIVE NATURE OF WATER QUALITY. EVENTUALLY MOST LAKES ARE FILLED WITH PLANT AND ANIMAL MATTER, BECOME BOGS AND THEN DRY LAND. THE TIME REQUIRED FOR

NATURE'S COMPLETION OF THIS PROCESS IS MEASURED IN MILLENIA; BUT THE PROCESS IS ACCELERATED SIGNIFICANTLY BY LARGE QUANTITIES OF ORGANIC MATERIAL DISCHARGED INTO THE LAKES.

GINDLER (CLARK, 1976) CONTINUES, "IN A BROAD SENSE 'WATER QUALITY' REFERS TO PHYSICAL, CHEMICAL, BIOLOGICAL, RADIOLOGICAL, AND OTHER PROPERTIES AFFECTING THE USEFULNESS OF A SPECIFIC QUANTITY OF WATER FLOWING AT A GIVEN VELOCITY. THE QUALITY OF WATER--WHETHER IT IS GOOD, BAD, OR INDIFFERENT--MAY BE DUE TO NATURAL CAUSES OR TO MAN'S ACTIVITIES OR TO BOTH." IN LIKE MANNER, THE QUANTITY AND VELOCITY OF WATER MAY BE SIGNIFICANT IN RELATION TO QUALITY FACTORS--AGAIN, FOR PARTICULAR PURPOSES. BY CONTRAST, GINDLER SUGGESTS, "THE TERM 'WATER POLLUTION' REFERS TO ANY MAN-MADE ALTERATION OF THE QUALITY OF WATER THAT APPRECIABLY IMPAIRS ITS USEFULNESS FOR A PARTICULAR PURPOSE. THIS DEFINITION APPEARS TO COMPORT WITH COMMON USAGE, ALTHOUGH NARROWER DEFINITIONS HAVE BEEN USED OR PROPOSED--E.G., IN *CAL. WATER CODE* (§ 13005) POLLUTION IS DEFINED AS "AN IMPAIRMENT OF THE QUALITY OF THE WATERS OF THE STATE BY *SEWAGE OR INDUSTRIAL WASTE*" THAT DOES NOT CONSTITUTE AN ACTUAL HEALTH HAZARD BUT DOES "ADVERSELY AND *UNREASONABLY* AFFECT SUCH WATERS" FOR BENEFICIAL USES (EMPHASIS ADDED). IN *RESTATEMENT, TORTS*, COMMENT B TO § 832 (1939), "POLLUTION OF WATERS", IS DEFINED AS:

> "Their impregnation with refuse or noxious substances. When water is polluted it may cause harm in a variety of ways. (On the other hand,) 'Contamination' is a kind, or perhaps a degree of pollution, but 'contamination' usually connotes a hazard to health.
>
> Hence, the term 'water quality' is not used here merely as a euphemism for the term 'water pollution', which is a more traditional and pungent phrase...'pollution' is one kind of alteration of quality which renders water undesirable for some beneficial use...(therefore,) pollution may be used to denote partial impairment of the usefulness of water for a particular purpose; the term should not be limtied to describing alterations in quality which render water totally unusable."

GINDLER CONCLUDES "A MODERN TREND IS THE EFFORT TO PROVIDE WATER-QUALITY CONTROL RATHER THAN SOLELY TO PREVENT WATER POLLUTION. THIS DISTINCTION BETWEEN QUALITY CONTROL AND PREVENTION OF POLLUTION IS VERY SIGNIFICANT IN CONNECTION WITH THE MANIFOLD REUSE THAT MUST BE MADE OF WATER. TO BE REUSABLE, WATER MUST BE MAINTAINED AT A SUITABLE QUALITY. DEGRADATION OF WATER QUALITY BY A SINGLE USER CAN REDUCE THE NUMBER OF TIMES THAT THE WATER MAY BE REUSED, EVEN IF IT DOES NOT POLLUTE THE WATER TO THE POINT OF BEING UNUSABLE BY THE NEXT USER DOWNSTREAM."

FINALLY, SOME OBSERVATIONS BY THE NATIONAL ACADEMY OF SCIENCES (1966), APPEAR TO BE INSTRUCTIVE BOTH HERE (DEFINITIONS OF "POLLUTION") AND LATER WITH RESPECT TO THE COURT CASES ON THE GREAT LAKES (RESERVE MINING COMPANY). THE COMMITTEE ON POLLUTION STATES:

> Pollution is an undesirable change in the physical, chemical, or biological characteristics of our air, land, and water that may or will harmfully affect human life or that of other desirable species, our industrial processes, living conditions, and cultural assets; or that may or will waste or deteriorate our raw material resources. Pollutants are the residues of the things we make, use, and throw away. Pollution increases not only because as people multiply the space available to each person becomes smaller, but also because the demands per person are continually increasing, so that each throws away more year by year. As the earth becomes more crowded, there is no longer an "away". One person's trash basket is another's living space.

THIS CHAPTER IS IN THE PROCESS OF BEING EXPANDED

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GLOSSARY

ASSIMILATIVE CAPACITY: the upper limit on the assimilative services of the environment. Once this capacity is exceeded potentially serious harm may result.

ASSIMILATIVE SERVICES: the ability of the environment to process (assimilate) limited quantities of emissions from modern society with no apparent harm to humans or other living organisms.

BENEFIT-COST ANALYSIS: a process of making decisions wherein the benefits and the costs of alternative courses of action are weighed. Benefits in excess of costs are normally considered to be the necessary condition for proceeding with an alternative.

COST-EFFECTIVENESS ANALYSIS: a process of making decisions where the benefits are not measured, but the costs of various alternatives for obtaining those benefits are carefully calculated. The normal decision is one which results in the benefits being obtained in the most cost-effective (least-cost) manner.

EXISTENCE VALUE: the value that would be attached to something by virtue of its existence even though the individual would never make direct use of it; its value derives from knowledge of its existence.

IRREVERSIBILITIES: changes made in the natural environment which tend to be technically and economically impossible to correct. The extinction of an endangered species is an example of an irreversibility, as would the extinction of any life form. To fill the Grand Canyon with dams and lakes would be practically irreversible, although perhaps with enough money the dams might someday be destroyed and all of the accumulated sediment dredged out.

MARGINAL BENEFITS: the benefits obtained through the last unit of something being carried out.

MARGINAL DAMAGES: the costs incurred through the last unit of something being carried out.

OPTION VALUE: the value that would be attached to something because the individual wished to have the option of someday making use of the thing in question.

PUBLIC GOOD: a good or a service when once provided by either the government or the private sector becomes freely available to all who wish to use it. National defense is often cited as the archtypical public good--it is impossible to provide it to you without also providing it to me. We may value its provision quite differently, but we cannot escape the fact that it is available in equal quantities to all members of the polity.

TRANSACTION COSTS: the necessary costs of participants in an exchange or a bargain to obtain necessary information, to contract with the other party, and to enforce the agreement.

LAKE ECONOMICS

A STUDY OF LAKE ECONOMICS INVOLVES AT LEAST FIVE COMPONENTS: (1) THOSE FACTORS LEADING TO A DETERIORATION IN WATER QUALITY; (2) THE ALTERNATIVES FOR IMPROVING WATER QUALITY; (3) AN ECONOMIC ANALYSIS OF WATER QUALITY IMPROVEMENTS; (4) AN ANALYSIS OF WHO BENEFITS FROM WATER QUALITY IMPROVEMENTS; AND (5) AN ANALYSIS OF WHO PAYS THE COSTS OF WATER QUALITY IMPROVEMENTS. EACH OF THESE COMPONENTS WILL COMPRISE A MAJOR SECTION IN THE TEXT THAT FOLLOWS.

ECONOMIC FACTORS LEADING TO DETERIORATION IN WATER QUALITY

IN RATHER GENERAL TERMS, WATER QUALITY IS REDUCED BELOW SOME NATURAL LEVEL BY THE FACT THAT HUMAN ACTIVITY GENERATES NON-MARKETABLE BY-PRODUCTS, THE DISPOSAL OF WHICH IS COSTLY. THE PROCESS OF CREATING MANUFACTURED GOODS IS ONE OF UTILIZING CERTAIN RAW MATERIALS IN COMBINATION WITH LABOR AND CAPITAL; ONE PRODUCT IS INTENTIONAL AND HAS A MARKET, THE OTHER IS AN UNWANTED BY-PRODUCT WITHOUT A MARKET. THE ABSENCE OF A MARKET RENDERS IT VALUELESS TO THE ENTREPRENEUR, AND MEANS THAT ITS DISPOSAL COSTS DETRACT FROM THE ECONOMIC VIABILITY OF THE ENDEAVOR. THE EASY THING TO DO IS TO DISCARD THIS BY-PRODUCE AS CHEAPLY AS POSSIBLE. IT IS, OF COURSE, NO GREAT PUZZLE WHY MANY INDUSTRIES ARE LOCATED ALONG WATER BODIES. JUST AS EARLY TRANSPORTATION RELIED UPON THE CHEAPNESS OF WATER TO CARRY RAW MATERIALS AND FINISHED PRODUCTS RATHER THAN LAND ROUTES, CURRENT BY-PRODUCT TRANSPORTATION AWAY FROM THE SITE DOES LIKEWISE.

FOR CERTAIN TYPES OF BY-PRODUCTS, THE PROCESS OF BEING CARRIED AWAY INVOLVES MORE THAN MERE TRANSPORTATION; THERE IS SOME ABILITY OF WATER BODIES TO ASSIMILATE CERTAIN BY-PRODUCTS SUCH THAT RECOVERY OF PRE-EMISSION WATER QUALITY IS SOMETIMES POSSIBLE. WHEN OXYGEN-DEMANDING MATERIAL IS DISCARDED INTO WATER THERE IS AN OXYGEN SAG WHICH EVENTUALLY CAN BE RESTORED TO "NORMAL" CONDITIONS; MECHANICAL OR NATURAL AERATION IS OFTEN HELPFUL HERE. THIS ASPECT OF BY-PRODUCT DUMPING IS REFERRED TO AS THE ASSIMILATIVE SERVICES OF THE RECEIVING WATER BODY. THERE IS AN ASSIMILATIVE CAPACITY FOR THESE TYPES OF EFFLUENTS AND ONCE EXCEEDED, OTHER DAMAGE--FOR INSTANCE TO FISH LIFE--MAY RESULT.

Under conditions of rather low population density and a rather meager technological setting, water quality is not likely to be seriously affected. This does not necessarily hold for fecal bacteria, but leaving this problem aside for the moment, primitive economic organization is generally less polluting than is a more advanced economy. Once population becomes concentrated near water bodies--or once technology becomes reliant upon chemicals or very high temperatures--then the kinds of pollution found in Lake Michigan become more prevalent.

Economists are inclined then to ask about another set of issues, and these pertain to the tastes and preferences of the community or society. Until quite recently, the public was inclined to ignore many of the by products of industrial progress with the feeling that it was "necessary", or it had "always been that way", or that there was "nothing at all wrong with it". While water quality can be terrible from an ecological point of view, nothing will be done about it until someone is convinced that the situation is "wrong". And this is where the problems enter, for *wrong* implies some concept about the way things *ought to be* and that involves value judgements.

Economics is not at all equipped to help out here. What *ought to be* is a social choice problem--the resolution of which has economic elements, but other elements as well. One argument that might be used to argue that it is wrong would be that all water is now seriously polluted and there ought to be at least a few places returned to their natural state. This, then, introduces scarcity, a concept at the heart of economics. Or someone else might point out that certain firms and municipalities must pay a great deal of money to clean up the water prior to its use. This also introduces economic calculus into the problem; now it is one of balancing the cost savings to the emittor against the clean-up costs of the water user. Economics can be very helpful here, but there is still an element of judgment in terms of which party *ought to* bear those costs.

The environmental awareness of the 1970's is a manifestation of changing tastes and preferences. Until trees began to be perceived as something other than future houses and fences, they had little value as standing timber; until wetlands began to be valued as wildlife habitat or as scenic areas, they were only impediments to growing more corn. Thus, changing tastes and preferences have a significant impact upon how "pollution" is defined. Is pollution only present when fish are killed; when waves foam with detergent; or when the water smells? To a large degree, pollution is defined by what it is we consider to be scarce.

Hence, an economist would be inclined to look at the problem of pollution in Lake Michigan as the coming together of

INCREASED POPULATION DENSITY AND A TECHNOLOGY WHICH PERMITS AN EVER-INCREASING IMPACT UPON THE ASSIMILATIVE CAPACITY OF THE LAKE. COUPLED WITH THIS INCREASING CAPACITY TO FOUL THE LAKE IS A DECREASING TOLERANCE FOR SUCH FOULING; THIS IS THE CHANGING TASTES AND PREFERENCES REFERRED TO ABOVE. INDEED, THERE IS AN INTERESTING INTERPLAY HERE BETWEEN TASTES AND PREFERENCES AND TECHNOLOGY; EACH FEEDS THE OTHER WITH RESPECT TO POLLUTION AND POLLUTION ABATEMENT. WHEN NO TECHNOLOGICAL ALTERNATIVE EXISTED TO WOOD-BURNING IN LONDON, PEOPLE COULD DISLIKE THE PALL THAT HUNG OVER THAT CITY, BUT COULD DO NOTHING ABOUT THE PROBLEM. ONCE TECHNOLOGICAL ALTERNATIVES BECOME POSSIBLE, THEN PEOPLE CEASE TO BE SO SANGUINE. LIKEWISE IT IS THE EVENTUAL DISSATISFACTION WITH THE STATUS QUO AS A RESULT OF A CHANGE IN TASTES AND PREFERENCES THAT CAN SPUR THE SEARCH FOR TECHNOLOGICAL ALTERNATIVES AND SOLUTIONS TO A POLLUTION PROBLEM.

BUT WHAT HAPPENS WHEN TASTES AND PREFERENCES CHANGE? WHAT TAKES PLACE WHEN THE VALUES WHICH WE PLACE UPON CERTAIN ENVIRONMENTAL ATTRIBUTES (SUCH AS CLEAN WATER) CHANGE? WHAT IS OCCURRING WHEN NEW-FOUND SCARCITIES ARISE? THE OBVIOUS ANSWER IS THAT CONFLICT OCCURS. WHY IS THIS NECESSARILY SO? THE SIMPLE ANSWER IS THAT ECONOMIC INTERESTS EMERGE AS A RESULT OF ANY ON-GOING ACTIVITY. WHEN PEOPLE BEGIN TO VALUE FORESTS IN THE NATURAL STATE, LOGGERS AND THE TIMBER INTERESTS ARE THREATENED. WHEN PEOPLE BEGIN TO QUESTION THE FILLING OF WETLANDS, IT IS FARMERS WHO ARE THREATENED BY THE POSSIBILITY THAT THEY MAY NOT BE ABLE TO INCREASE THEIR CORN PRODUCTION ON LAND WHICH THEY OWN. WHEN PEOPLE COMPLAIN ABOUT THE KILLING OF WILDLIFE, IT IS THE HUNTERS WHO ARE THREATENED, ALONG WITH THE ECONOMIC ACTIVITY WHICH DEPENDS ON HUNTING. WHEN CITIES GO ON THE LOOKOUT FOR FUTURE LANDFILL SITES, IT IS THE RURAL RESIDENTS WHO ARE THREATENED. WHEN THOSE WHO OBJECT TO INDUSTRIAL POLLUTION IN LAKES AND STREAMS ATTEMPT TO BRING THAT TO A HALT, IT IS THE MANAGERS AND OWNERS OF SAID INDUSTRY WHO ARE THREATENED, AND SO ON.

ACTIVE INTERESTS AND THREATENED INTERESTS ARE AT THE NEXUS OF EVERY CONFLICT OVER THE ENVIRONMENT AND THE ENVIRONMENTAL QUALITY; THIS IS NO LESS TRUE IN LAKE MICHIGAN THAN IT IS ANYWHERE. AND AT THE CRUX OF THIS CONFLICT IS THE PRESUMED "RIGHT" OF THE PROTAGONISTS TO TREAT RESOURCES AS THEY PLEASE. FARMERS HOLD TITLE TO THEIR LAND AND ARGUE THAT THIS GIVES THEM THE "RIGHT" TO DO WITH IT AS THEY WISH, INCLUDING ALLOWING IT TO WASH AWAY IN A RAINSTORM IF THEY SO CHOOSE. A LANDOWNER DECIDES TO FILL A WETLAND AND CONSTRUCT AN APARTMENT COMPLEX ON THE SITE AND CANNOT UNDERSTAND HOW THIS "RIGHT" CAN BE ABRIDGED BY THE STATE.[1] A CHEMICAL FIRM HAS BEEN USING THE RIVER AS A WASTE DISPOSAL MEDIUM AND HAS BUDGETED ITS CAPITAL EXPANSION PLANS, ITS PRODUCT LINE, ITS PRICE

STRUCTURE, ITS WAGE AND SALARY PACKAGE, AND ITS DIVIDENT PLAN FOR THE NEXT TEN YEARS ON THE ASSUMPTION THAT IT WILL BE ABLE TO CONTINUE USING THE RIVER. HOW IS IT POSSIBLE NOW TO TAKE AWAY ITS "RIGHT" TO USE THE RIVER?

SOME OF THESE PRESUMED RIGHTS ARE COVERED BY THE TERM "PROPERTY RIGHT" AS IN THE CASE OF THE FARMER AND THE OWNER OF THE MARSH. BUT THE USE OF THE RIVER IS NOT A PROPERTY RIGHT IN AN ABSOLUTE SENSE. RATHER, IT IS A LONG-ESTABLISHED USE WHICH MAY HAVE SOME CREDENCE IN THE LAW. IT IS POSSIBLE TO THINK OF THIS CONFLICT AS ONE IN WHICH THOSE WHO WANT TO USE THE ENVIRONMENT FOR PERSONAL GAINS ARE CLASHING WITH THOSE WHO VIEW THE ENVIRONMENT AS PUBLIC DOMAIN.

ONE MIGHT ASK WHY IT IS THAT ECONOMICS CONCERNS PROPERTY RIGHTS; ISN'T THAT WHAT LAWYERS WORRY ABOUT? THE ANSWER IS THAT ECONOMICS IS CONCERNED WITH THE USE OF SCARCE RESOURCES AND THE ALLOCATION OF THOSE RESOURCES AMONG COMPETING USES. THE OWNERSHIP AND CONTROL OF THOSE RESOURCES MUST BE CLEAR AND UNAMBIGUOUS BEFORE THEY CAN BE ALLOCATED TO ONE USE OR THE OTHER. PERHAPS SEVERAL EXAMPLES WILL BE HELPFUL. WHEN YOU WALK INTO A CLOTHING STORE, THE OWNERSHIP OF THE MERCHANDISE IS INCONTROVERTIBLE, THAT IS, PROPERTY RIGHTS ARE CLEARLY DEFINED. YOU MAKE A DECISION ON A PURCHASE AND THEN EXCHANGE SOMETHING OVER WHICH PROPERTY RIGHTS ARE EQUALLY UNDISPUTABLE (YOUR MONEY) FOR THE DESIRED ITEM. ONCE THE TRANSACTION IS COMPLETE YOU ARE THE UNDISPUTED OWNER OF THE ITEM, AND THE MERCHANT IS EQUALLY SECURE IN THE OWNERSHIP OF THE MONEY. THERE IS A SIMILAR SITUATION IN LABOR MARKETS; YOU EXCHANGE YOUR LABOR-TIME FOR A PREDETERMINED AMOUNT OF MONEY. BUT WHEN IT COMES TO THE USE OF MANY ENVIRONMENTAL RESOURCES, PROPERTY RIGHTS ARE EITHER: (1) UNDETERMINED; OR (2) SPECIFIED BUT UNENFORCED. THIS IS WHERE MUCH OF THE EMPHASIS HAS BEEN FOCUSED IN THE ENVIRONMENTAL MOVEMENT--EITHER TO ENFORCE EXISTING PROPERTY RIGHTS IN THE ENVIRONMENT, OR TO SPECIFY THEM IN SUCH A WAY THAT THE ENVIRONMENT IS ACCORDED GREATER PROTECTION. UNTIL NEW KNOWLEDGE MADE IT OBVIOUS THAT SERIOUS ENVIRONMENTAL HARM WAS OCCURRING--OR UNTIL TASTES AND PREFERENCES CHANGED--THERE WAS LITTLE CONCERN OVER WHO HAD THE PROPERTY RIGHTS IN AIR, WATER, ETC. ONCE THESE RESOURCES BECAME SCARCE AND VALUABLE, THEIR USE AND CONTROL BECAME OF GREAT INTEREST.

IN SUMMARY THEN, POLLUTION IS AN ECONOMIC ISSUE FOR A NUMBER OF REASONS. FIRST, MODERN LIFESTYLES CREATE EVER-MORE OFFENSIVE BY-PRODUCTS. SECOND, OUR TASTES AND PREFERENCES HAVE CHANGED SO THAT WE NO LONGER CONSIDER THE ENVIRONMENT TO BE MERELY A GARBAGE DUMP, AND WE HAVE THE TECHNOLOGICAL OPTIONS FOR REDUCING MANY SERIOUS POLLUTION PROBLEMS. THIRD, ECONOMISTS BECOME INVOLVED IN

POLICY FOR POLLUTION CONTROL BECAUSE IT INVOLVES THE COMMITMENT OF SCARCE FINANCIAL RESOURCES FOR ABATEMENT AND BECAUSE THERE ARE TECHNOLOGICAL POSSIBILITIES WHICH WILL REDUCE THE UNWANTED BY-PRODUCTS FROM A GIVEN QUANTITY OF DESIRED PRODUCT.

THE ECONOMICS OF POLLUTION CONTROL IS CONCERNED WITH FINDING AN APPROPRIATE LEVEL OF POLLUTION CONTROL AND/OR WITH HELPING TO DETERMINE THE MOST COST-EFFECTIVE MEANS FOR ATTAINING A PRE-SPECIFIED LEVEL OF POLLUTION CONTROL.

IMPROVING WATER QUALITY IN THE LAKE: AN OVERVIEW OF THE ALTERNATIVES

THE FOLLOWING DISCUSSION WILL BE LIMITED TO A CLASS OF POLLUTANTS THAT CAN BE CHARACTERIZED AS NON-TOXIC, AND OFTEN SUBTLE; EXAMPLES ARE PHOSPHOROUS EMISSIONS, THERMAL DISCHARGES FROM POWER PLANTS, NUTRIENT RUNOFF FROM AGRICULTURAL LANDS, AND "ACID RAIN" FROM INDUSTRY WHICH IS SAID TO ACCOUNT FOR 30-40 PERCENT OF THE TOTAL LOADINGS OF COPPER AND LEAD IN THE UPPER LAKES.[2] ALL OF THESE HAVE IN COMMON THE FACT THAT THE ENVIRONMENT CAN ABSORB A CERTAIN QUALITY WITHOUT UNDUE HARM; THAT THEY ARE NOT READILY OBSERVABLE; AND THAT THE COMPLETE ELIMINATION OF THEM WOULD BE EXTREMELY EXPENSIVE.

PRESENTLY, THERE IS A SHARP DIVISION OF OPINION AMONG INDIVIDUALS AS TO WHETHER OR NOT SUCH EMISSIONS SHOULD BE BANNED REGARDLESS OF THE COST. WHEN DEALING WITH TOXIC ELEMENTS A TOTAL BAN IS QUITE EASY TO DEFEND. BUT WITH THESE TYPES OF POLLUTANTS, THE CASE FOR A COMPLETE BAN IS LESS OBVIOUS. ECONOMICS IS CONCERNED WITH HELPING TO CHOOSE AMONG SEVERAL OPTIONS. A POSITION IN FAVOR OF A COMPLETE BAN IS ONE THAT REQUIRES NO ECONOMIC ANALYSIS; LIKEWISE THERE IS LITTLE ANALYSIS CALLED FOR IF THE STATUS QUO IS ACCEPTED. BUT, ON THE ASSUMPTION THAT THESE TWO EXTREMES ARE REJECTED, THEN THERE IS A ROLE FOR ECONOMICS, BASED ON THE 4 OPTIONS BELOW.

THESE OPTIONS FOR REDUCING POLLUTION IN LAKE MICHIGAN INCLUDE: (1) REDUCING TOTAL MATERIAL THROUGHPUT OF LAKESIDE RESIDENTS AND BUSINESSES; (2) TREATING THE RESIDUALS; (3) MAKING JUDICIOUS DISCHARGES; AND (4) INCREASING THE WASTE ASSIMILATIVE CAPACITY OF THE LAKE.[3]

REDUCING THROUGHPUT

ONE ATTRACTIVE OPTION FOR REDUCING POLLUTION IS TO ALTER THE TECHNOLOGY OF PRODUCTION WHICH YIELDS BOTH THE INTENDED PRODUCT, AND THE UNWANTED BY-PRODUCT (THE POLLUTANT). IN INDUSTRY THIS WOULD INVOLVE ADJUSTMENTS IN PROCESSES SUCH THAT APPROXIMATELY THE SAME LEVEL OF PRIMARY PRODUCT IS FORTHCOMING, YET LESS OF THE UNINTENDED PRODUCT RESULTS. IT IS HERE THAT THE UNFORTUNATE DICHOTOMY OF "JOBS OR THE ENVIRONMENT" ENTERS; IT IS UNFORTUNATE BECAUSE IT IS NOT AN ACCURATE DEPICTION OF THE TRADEOFFS BEFORE US. WHILE EXTENSIVE TECHNOLOGY

CHANGE IN INDUSTRIES CAN INDEED BE EXPENSIVE, THERE ARE GRADUAL STEPS WHICH ARE OFTEN POSSIBLE TO REDUCE THE BY-PRODUCTS ARISING FROM ECONOMIC ACTIVITY. IN HOUSEHOLDS, ONE OF THE MAJOR POLLUTANTS IS PHOSPHOROUS FROM DETERGENTS. HERE, "TECHNOLOGICAL CHANGE" WOULD INVOLVE SWITCHING TO LOW-PHOSPHATE DETERGENTS, A MOVE WHICH HAS BEEN WILLINGLY UNDERTAKEN BY MANY CONCERNED CITIZENS, AND BY OTHERS LIVING IN AREAS WHERE PHOSPHATES HAVE BEEN BANNED. ALTHOUGH LESS RELEVANT TO WATER POLLUTION IN LAKE MICHIGAN, A MOVE AWAY FROM EXCESSIVE PACKAGING--ESPECIALLY WITH NON-BIODEGRADABLE MATERIALS--IS AN EXAMPLE OF THIS SORT OF TECHNOLOGICAL CHANGE. ANOTHER OPTION FOR REDUCING POLLUTION IS FOR TASTES AND PREFERENCES TO CHANGE THEREBY LEADING TO ALTERED CONSUMPTION PATTERNS; SAIL BOATS DO NOT FOUL THE WATER AS DO MOTOR BOATS.

TREATING RESIDUALS

THE OPTION THAT SEEMS TO RECEIVE THE MOST ATTENTION IS THAT OF MERELY PROCEEDING AS WE HAVE AND THEN TREATING THE EFFLUENT OF INDUSTRIES AND MUNICIPALITIES. THIS STRATEGY IS NOT APPLICABLE TO NON-POINT SOURCE POLLUTION; NOR DOES IT INVOLVE TECHNOLOGICAL ADJUSTMENT WITHIN THE FACTORY (OR THE HOME). HOWEVER, TREATMENT OF RESIDUALS IS OFTEN QUITE RESPONSIVE--COSTWISE--TO TECHNOLOGICAL CHANGE AND HENCE A LEAST-COST STRATEGY MAY WELL BE A COMBINATION OF PROCESS CHANGE IN PRODUCTION, AND THEN SOME TREATMENT.

JUDICIOUS DISCHARGES

ALTHOUGH MORE PERTINENT FOR RIVERS WITH FLUCTUATING FLOW LEVELS, THERE MAY BE AN OPPORTUNITY TO REDUCE THE EFFECTS OF DISCHARGES--THOUGH NOT THE TOTAL DISCHARGES--BY A CAREFUL SELECTION OF TIMES TO DUMP WASTES. IN RIVERS, IT IS IMPORTANT TO AVOID PERIODS OF LOW FLOW SINCE THE ASSIMILATIVE CAPACITY IS THEN AT A MINIMUM. IN LAKE MICHIGAN THERE ARE PARTICULAR CURRENTS WHICH MAY CARRY UNDESIRABLE EFFLUENTS DIRECTLY INTO VULNERABLE AREAS, AND CAREFUL CONTROL CAN BE HELPFUL IN REDUCING THE DAMAGES FROM DUMPING.

AUGMENTING WASTE ASSIMILATIVE CAPACITY

THE FINAL OPTION IS ALSO MORE SUITED TO RIVERS WHERE RESERVOIRS CAN BE RELEASED TO DILUTE UNWANTED CONCENTRATIONS OF POLLUTANTS. BUT, IT IS POSSIBLE THAT THIS COULD ALSO BE USED IN LAKE MICHIGAN, PARTICULARLY WHERE DUMPING OCCURS IN TRIBUTARIES OR BAYS. IF THERE IS SOME CAPACITY FOR REGULATING THE FLOW OF THE RIVER THEN IT IS POSSIBLE TO REDUCE THE POTENTIAL DAMAGE FROM DISCHARGES.

IN SUMMARY, THEN, WE HAVE ONE OPTION WHICH REDUCES THE AMOUNT OF EFFLUENT OR DISCHARGE PER UNIT OF PRODUCE; ONE METHOD WHICH RELIES ON MERELY TREATING THE EFFLUENT; AND TWO METHODS WHICH DO NOT DEPEND UPON REDUCING DUMPING IN TOTAL, BUT INSTEAD RELY ON TIMING AND OTHER MEASURES TO REDUCE THE UNDESIRABLE SIDE-EFFECTS OF A GIVEN AMOUNT OF DISCHARGE.

LET'S NOW TURN TO A DISCUSSION OF THE POLICY ISSUE OF HOW MUCH DAMAGE SHOULD BE PERMITTED--THAT IS, HOW MUCH ABATEMENT OF DISCHARGES SHOULD THERE BE?

THE ECONOMICS OF POLLUTION ABATEMENT

ON THE ASSUMPTION THAT WE ARE INTERESTED IN SPENDING POLLUTION CONTROL DOLLARS WISELY, THEN WE ARE AUTOMATICALLY CONCERNED WITH ECONOMIC EFFICIENCY--I.E., WE WANT THE MOST FOR OUR MONEY. FEW ARE IN FAVOR OF WASTE, AND HENCE THIS EFFICIENCY IMPERATIVE IS NOTHING MORE THAN TRYING TO WASTE AS FEW FINANCIAL RESOURCES AS POSSIBLE. ECONOMISTS ARE TEMPTED TO BEGIN THIS SEARCH FOR AN EFFICIENT LEVEL OF POLLUTION CONTROL BY TALKING IN TERMS OF AN OPTIMUM LEVEL OF POLLUTION CONTROL. SOME MIGHT BE TEMPTED TO RESPOND BY SAYING THAT THE OPTIMUM LEVEL OF POLLUTION CONTROL IS ABSOLUTE PROHIBITION; FOR TOXICS, AND FOR SOME OF THE TYPES OF DISCHARGES DISCUSSED EARLIER, THIS MAY BE TRUE. HOWEVER, AS POINTED OUT EARLIER, THERE ARE SOME DISCHARGES WHICH CAN BE PROCESSED BY THE ENVIRONMENT WITH LITTLE DAMAGE EITHER TO HUMANS OR OTHER ORGANISMS. OUR MODEL OF OPTIMUM POLLUTION CONTROL WILL THUS START WITH THIS TYPE OF DISCHARGE IN MIND. THAT IS, GIVEN THE ASSIMILATIVE CAPACITY OF THE ENVIRONMENT FOR CERTAIN BY-PRODUCTS OF MODERN CIVILIZATION--EXHAUST FROM CARS, AGRICULTURAL NUTRIENTS, SOIL EROSION, ETC.--THE RELEVANT QUESTION FOR RATIONAL POLICY IS ONE OF FINDING THE IDEAL LEVEL AT WHICH ABATEMENT EFFORTS SHOULD BE CARRIED OUT.

BEFORE PROCEEDING, SOME PRELIMINARY CONCEPTS ARE NEEDED. A GREAT DEAL OF ECONOMICS IS CONCERNED WITH MAKING DECISIONS "AT THE MARGIN"--THAT IS, AS THE LAST UNIT OF SOMETHING IS BEING CONTEMPLATED. CONSIDER AN EXAMPLE. AS A PURE ORGANIC GARDNER, YOU ESCHEW THE USE OF CHEMICALS TO CONTROL PESTS. BUT, YOU ALSO MUST HOLD DOWN A JOB DURING THE DAY AND HENCE LABOR FOR USE IN YOUR GARDEN IS A VERY SCARCE ITEM. A NEIGHBOR GIRL JUST HAPPENS TO BE IN NEED OF A SUMMER JOB AND SOON A BARGAIN IS STRUCK; YOU AGREE TO PAY HER TO COLLECT PESTS FROM YOUR RATHER LARGE GARDEN. NOW, YOU HAVE SOME NOTION AS TO THE DAMAGES WHICH ARISE FROM THESE PESTS, AND YOU CALCULATE HOW MUCH PER HOUR YOU MUST PAY YOUR NEW PEST-CONTROL ENGINEER, AND YOU REACH A DECISION THAT 3 HOURS PER DAY IS THE OPTIMAL AMOUNT OF TIME FOR HER TO SCAVENGE FOR PESTS. YOU KNOW THAT ANY LESS THAN THAT WOULD RESULT IN TOO MANY OF THEM ESCAPING HER SHARP EYE AND QUICK NET. YOU ALSO KNOW THAT ANY MORE THAN THAT WOULD MEAN HER TIME WAS LESS AND LESS PRODUCTIVE IN TERMS OF PESTS APPREHENDED PER DAY. YOU HAVE MADE A DECISION AT THE MARGIN. YOU HAVE DECIDED THAT THE BENEFITS OF PAYING HER FOR THAT THIRD HOUR EXCEED THE COST OF THAT HOUR (HER HOURLY RATE), BUT THAT THE BENEFITS OF A FOURTH HOUR (IN TERMS OF REDUCED

DAMAGE FROM THE PESTS CAUGHT DURING THAT HOUR) ARE LESS THAN THE COST (AGAIN, HER HOURLY WAGE). YOU HAVE CONCLUDED THAT THE MARGINAL BENEFITS FOR THE FOURTH HOUR PER DAY ARE LESS THAN THE MARGINAL COSTS. THIS IS STYLIZED IN FIGURE 1.

WE ALL MAKE DECISIONS AT THE MARGIN ON A DAILY BASIS BY BALANCING THE BENEFITS AGAINST THE COSTS. WE ARE INTERESTED HERE IN APPLYING THE SAME DECISION CRITERIA TO POLLUTION CONTROL. WE KNOW THAT IF EVERY LAST POUND OF PHOSPHOROUS COULD BE KEPT OUT OF THE LAKE THAT ALGAE GROWTH WOULD BE SLOWED. BUT, WE ALSO KNOW THAT IT WOULD BE VERY, VERY EXPENSIVE TO ACTUALLY INTERCEPT THAT LAST POUND OF PHOSPHOROUS AND TO PREVENT ITS ENTRY INTO THE LAKE.

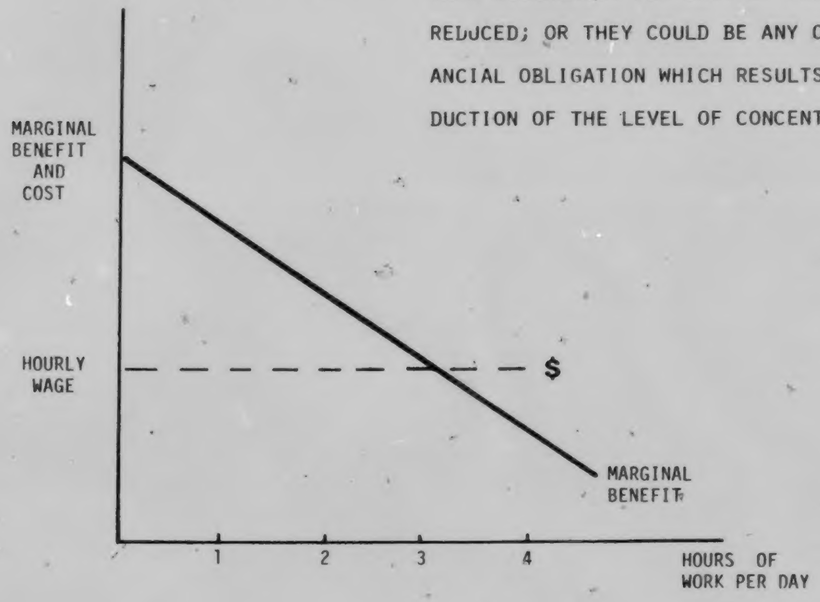

FIGURE 1.

LET US SIMPLIFY THE MATTER BY REFERRING TO POLLUTION IN LAKE MICHIGAN AS "CONCENTRATION OF RESIDUALS", AND ASSUME THAT THE LEVEL OF WATER QUALITY IN THE LAKE IS INVERSELY RELATED TO THIS LEVEL OF CONCENTRATION OF RESIDUALS--MORE RESIDUALS IMPLIES LOWER WATER QUALITY, AND CONVERSELY. WE WILL ALSO ASSUME THAT IT IS POSSIBLE TO DEPICT A UNIQUE RELATIONSHIP BETWEEN THIS CONCENTRATION OF RESIDUALS AND DAMAGES TO VARIOUS INDIVIDUALS. FINALLY, WE ASSUME THAT IT IS POSSIBLE TO QUANTIFY THE RELATIONSHIP BETWEEN THE CONCENTRATION OF RESIDUALS IN THE LAKE AND THE COSTS THAT WOULD HAVE TO BE INCURRED TO REDUCE THAT CONCENTRATION. IN THIS CASE THOSE COSTS COULD BE TREATMENT COSTS; THEY COULD BE THE COSTS OF CHANGES IN TECHNOLOGY SUCH THAT DISCHARGES PER UNIT OF PRODUCE ARE REDUCED; OR THEY COULD BE ANY OTHER FINANCIAL OBLIGATION WHICH RESULTS IN A REDUCTION OF THE LEVEL OF CONCENTRATION OF

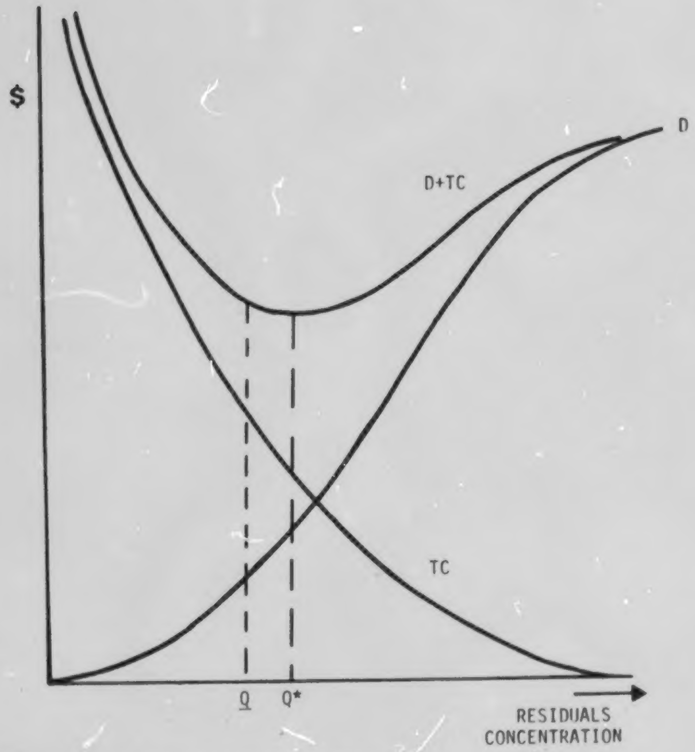

FIGURE 2. AN ECONOMIC MODEL OF POLLUTION CONTROL

RESIDUALS IN THE LAKE. NOW IT IS POSSIBLE TO DEPICT THESE RELATIONSHIPS AS IN FIGURE 2.

THE CURVE LABELED TOTAL DAMAGES DEPICTS THE RELATIONSHIP BETWEEN THE LEVEL OF CONCENTRATION OF RESIDUALS IN THE LAKE AND THE HARM THAT COMES FROM THAT CONCENTRATION. NOTICE THAT AT LOW LEVELS OF CONCENTRATION THE DAMAGE IS NOT TOO GREAT, BUT THAT AS THE CONCENTRATION BEGINS TO INCREASE, DAMAGES ALSO INCREASE BUT AT AN INCREASING RATE. IT IS EVEN POSSIBLE THAT AT VERY HIGH LEVELS OF CONCENTRATION, DAMAGES WOULD CEASE TO INCREASE FURTHER FOR THE SIMPLE REASON THAT THERE IS NO MORE HARM TO BE DONE. WE OBTAIN A SIGMOID CURVE SUCH AS D IN FIGURE 2.

NOW CONSIDER THE COSTS OF PREVENTING THE CONCENTRATION OF RESIDUALS, HERE REFERRED TO AS POLLUTION CONTROL COSTS. THE CURVE TC IN FIGURE 2 DEPICTS THE TOTAL COSTS OF CONTROLLING POLLUTION IN LAKE MICHIGAN. AT THE FAR RIGHT, WHERE RESIDUALS CONCENTRATION IS THE GREATEST, POLLUTION CONTROL COSTS ARE ZERO. AS EFFORTS ARE UNDERTAKEN TO REDUCE CONCENTRATIONS (MOVING TO THE LEFT) THOSE COSTS BEGIN TO RISE. IN THE EARLY STAGES IT MAY BE POSSIBLE TO INSTALL RATHER INEXPENSIVE COLLECTORS; TO CHANGE MANUFACTURING PROCESSES SLIGHTLY TO REDUCE BY-PRODUCTS; TO REDUCE PHOSPHOROUS EMISSIONS FROM MUNICIPAL WASTE TREATMENT

FACILITIES, ETC. IN THE EARLY STAGES OF REDUCING CONCENTRATIONS THEN, SUBSTANTIAL REDUCTION CAN OFTEN BE EFFECTED AT A RATHER LOW COST. HOWEVER, AS THE MORE COST-EFFECTIVE MEASURES ARE ADOPTED THE TASK BECOMES MORE DIFFICULT; COSTS BEGIN TO INCREASE AT AN INCREASING RATE. AS WE MOVE TO THE LEFT IN FIGURE 2, TOWARD REDUCED CONCENTRATION OF RESIDUALS, THE COSTS BECOME EVEN MORE PROHIBITIVE; AT THE MARGIN, WE ARE PAYING A VERY DEAR PRICE FOR YET SMALLER INCREMENTS OF POLLUTION REDUCTION. THIS IS ANALOGOUS TO YOU PAYING THE NEIGHBOR GIRL TO WORK 8-10 HOURS PER DAY IN SEARCH OF THE LAST FEW PESTS; HER PRODUCTIVITY SUFFERS AS EACH SUBSEQUENT PEST BECOMES EVER MORE DIFFICULT TO APPREHEND. YOU MAY EVEN BE PAYING HER TO REDUCE THE PEST POPULATION BELOW THE LEVEL WHICH COULD BE BORNE BY THE PLANTS AND THE PEST'S NATURAL PREDATORS.

FROM AN EFFICIENCY POINT OF VIEW, IT WOULD BE IDEAL TO FIND THAT LEVEL OF RESIDUALS CONCENTRATION WHERE THE GAIN OF REDUCING POLLUTION DAMAGE BY ONE MORE DOLLAR IS JUST OFFSET BY THE COST OF ACHIEVING THAT GAIN. THAT IS, WE ARE MAKING A MARGINAL DECISION WHICH ACCOUNTS FOR THE BENEFITS OF POLLUTION REDUCTION AND THE COSTS OF THAT REDUCTION; THE REDUCTION IN DAMAGE IS EXACTLY EQUAL TO THE INCREASE IN COSTS. BECAUSE THE *SLOPE* OF THE TOTAL CURVES IS EQUAL TO THE CHANGE OF TOTAL COST OR TOTAL DAMAGES, RESPECTIVELY, WE CAN JUDGE THE *MARGINAL* COST OR THE *MARGINAL* DAMAGE DIRECTLY FROM THE TOTAL CURVES. REMEMBER IN THIS MODEL A REDUCTION IN DAMAGE IS CONSIDERED TO BE A BENEFIT, WHILE COSTS ARE POLLUTION-CONTROL COSTS. HENCE, USING MARGINAL ANALYSIS, THE OPTIMAL LEVEL OF POLLUTION CONTROL IS FOUND WHERE THE *RATE OF INCREASE* IN CONTROL COSTS (MARGINAL COST) IS EXACTLY OFFSET BY THE *RATE OF DECREASE* OF DAMAGES (INCREASE OF BENEFITS)--MARGINAL BENEFITS. GEOMETRICALLY THIS IS WHERE THE *SLOPE* OF TC IS EQUAL TO--BUT OPPOSITE IN SIGN FROM--THE SLOPE D. THIS OCCURS AT POINT Q^*.

WE COULD ALSO REACH THIS SAME CONCLUSION BY ASKING THE QUESTION: AT WHAT LEVEL OF POLLUTION CONTROL *AND* DUMPING OF RESIDUALS IS THE TOTAL COST TO US A MINIMUM? HERE, TOTAL COSTS INCLUDE *BOTH* CONTROL COSTS AND DAMAGE COSTS. TO DETERMINE THIS WE FIND THE VERTICAL SUM OF TC AND D FOR EVERY LEVEL OF RESIDUALS CONCENTRATION. AS BEFORE, THE OPTIMAL LEVEL OF POLLUTION CONTROL WOULD BE AT Q^*.

WHILE THE ABOVE SIMPLE MODEL IS USEFUL IN THINKING ABOUT THE CONCEPT OF AN OPTIMAL LEVEL OF POLLUTION CONTROL (AND, HENCE, OF RESIDUALS CONCENTRATION), IT IS VERY DIFFICULT TO OBTAIN A PRECISE ESTIMATION OF POLLUTION DAMAGES--E.G. BENEFITS FROM REDUCED POLLUTION. HENCE, FEW ECONOMISTS ADVOCATE THE SEARCH FOR AN *OPTIMUM OPTIMORUM*. INSTEAD, A MORE PRACTICAL POLICY OBJECTIVE IS TO DETERmine, through the political process, the appropriate level of residuals concentration, and then to seek the most cost effective way to achieve that level. In the model of Figure 2 we are using benefit-cost analysis to determine the optimum level of pollution control. The more feasible alternative is to use cost-effectiveness analysis to help us to achieve a pre-determined standard at the lowest possible cost to society. In the U.S., the 1972 Amendments to the Federal Water Pollution Control Act (P.L. 92-500) defined such standards in terms of "fishable and swimmable water". It might also be possible to define certain levels of dissolved oxygen (DO) as the acceptable stream or lake standard. In terms of Figure 2 we might assume that the curve D is not known, and merely decide that the "ideal" level of residuals concentration (the water quality standard) is to be at $\underline{Q}$.

An alternative to an ambient water quality standard is an effluent standard where general guidelines are given for various types of residuals. For instance, the International Joint Commission has adopted--through the 1972 Water Quality Agreement--an effluent standard of 1 mg/liter of phosphorous for the Lower Great Lakes. The presumption is that given the number of dischargers, an effluent concentration of this order would result in the desired level of ambient water quality (say $\underline{Q}$ in Figure 2). Of course if this assumption is not realistic, then an effluent standard of 0.75 mg/liter might be required to meet the ambient water quality goal.

Central to the determination of water quality standards arrived at through the political process is the notion of *bargaining* over the optimal level of pollution. Those individuals negatively disposed toward government action invariably advocate that governments stay out of the pollution control area and let those directly affected--firms and users--bargain out the optimal solution. There are several problems with this solution with respect to Lake Michigan; while they will be discussed in greater detail in the following section, it is important here to outline several difficulties with bargaining. First, it is safe to assume that all of those who will benefit from a cleaner lake are not in close enough proximity to engage in meaningful bargaining. Economists refer to the costs of such bargaining as transaction costs and for many potential beneficiaries these costs would be high indeed. Secondly, if we assume that it is receipients who are attempting to convince emittors to reduce their dumping, then they must be prepared to provide some financial incentive to industry or municipalities to reduce discharges. But because each individual cannot purchase exactly the le-

VEL OF WATER QUALITY MOST PREFERRED BY HIM/HER, BARGAINING IS MOST DIFFICULT. THAT IS, WATER QUALITY IS REFERRED TO AS A PUBLIC GOOD--IT IS IMPOSSIBLE TO PROVIDE YOU WITH A LEVEL OF WATER QUALITY IN LAKE MICHIGAN WITHOUT ALSO PROVIDING THAT SAME LEVEL TO ALL OF US. IF I DO NOT VALUE WATER QUALITY AS MUCH AS YOU DO THEN I AM LESS WILLING TO BARGAIN WITH POLLUTERS THAN YOU. THESE PUBLIC GOODS PROBLEMS--TO BE DISCUSSED IN MORE DETAIL BELOW--ARE VERY TROUBLESOME FOR BARGAINING. FINALLY, AND MOST SIGNIFICANTLY PERHAPS, THERE IS THE ETHICAL QUESTION OF WHY INDIVIDUALS WITH A STRONG PREFERENCE FOR CLEAN WATER IN LAKE MICHIGAN SHOULD HAVE TO OFFER POLLUTERS A FINANCIAL INDUCEMENT TO CEASE FOULING THE WATER. THIS IS THE ISSUE OF PRESUMPTIVE PROPERTY RIGHTS DISCUSSED ABOVE.

IF ONE ADVOCATES BARGAINING BETWEEN POLLUTERS AND RECIPIENTS OVER POLLUTION LEVELS UNDER THE CURRENT SITUATION, THEN IT IS EXPLICIT RECOGNITION THAT INDUSTRY AND MUNICIPALITIES HAVE A "RIGHT" TO DUMP WASTES; THEY CAN ONLY BE INDUCED TO STOP BY BEING PAID. CONSIDER HOW THIS DIFFERS FROM A SITUATION WHERE THOSE FAVORING CLEAN WATER HOLD THE "PROPERTY RIGHT" AND THOSE WISHING TO DUMP RESIDUALS MUST COME FORWARD WITH MONETARY INDUCEMENTS TO CONVINCE THE FORMER TO PERMIT DISCHARGES. IT IS SAFE TO SAY THAT WE WILL GET A DIFFERENT LEVEL OF WATER QUALITY DEPENDING UPON THE PRIOR ASSIGNMENT (OR PRESUMPTION) OF PROPERTY RIGHTS.[4]

AND SO, RATHER THAN BARGAINING BETWEEN EMITTORS AND RECIPIENTS, THE DETERMINATION OF WATER QUALITY STANDARDS THROUGH THE POLITICAL PROCESS IS AN EFFECTIVE WAY TO INSURE THE REPRESENTATION OF A WIDELY DIVERGENT SET OF TASTES AND PREFERENCES REGARDING DESIRED LEVELS OF POLLUTION CONTROL.

ONCE A STANDARD HAS BEEN AGREED UPON THE IMPORTANT POLICY ISSUE IS HOW THAT STANDARD WILL BE IMPLEMENTED OR ACHIEVED. THE 1972 AMENDMENTS TO THE FEDERAL WATER POLLUTION CONTROL ACT CREATED A NATIONAL POLLUTION DISCHARGE ELIMINATION SYSTEM WHERE PERMITS ARE ISSUED TO EACH SIGNIFICANT DISCHARGER SPECIFYING THE AMOUNT OF PERMISSIBLE DUMPING. ON THE OTHER HAND, MANY ECONOMISTS TEND TO PREFER A SYSTEM OF EFFLUENT CHARGES WHICH ARE BASED ON UNITS DISCHARGED--THIS IS THE EMISSIONS TAX. WHAT ARE THE ADVANTAGES OR DISADVANTAGES OF THE TWO APPROACHES?

A SYSTEM OF REGULATED DISCHARGES FROM A NUMBER OF POLLUTERS REQUIRES THAT A REGULATORY AGENCY ALLOCATE THE TOTAL PERMISSIBLE POLLUTION LOADING AMONG FIRMS AND MUNICIPALITIES CURRENTLY DUMPING EFFLUENT. THE ASSIGNMENT OF EACH DISCHARGER'S SHARE OF THE TOTAL IS LIABLE TO BE A DIFFICULT TASK; IT IS EVEN MORE DIFFICULT TO BE CERTAIN THAT THE LEAST-COST ALLOCATION OF DISCHARGE PERMITS HAS BEEN OBTAINED. CONSIDER A SITUATION IN WHICH WE ASSUME ONLY 5 INDUSTRIAL DIScharges on the shores of Lake Michigan and one type of pollutant. If we assume that the technologies of the 5 differ slightly then their abatement costs will also differ; each will experience a different cost for the same level of emission reduction. To meet the permissible load we must then ask: "Should they all be required to reduce their current emissions by a fixed percentage?" If the answer is yes, then the reductions will entail a greater total cost burden than if the "low-cost abators" reduced their dumping proportionately more than the "high-cost abators". But such differential treatment is politically difficult and so excessive abatement costs would likely be incurred by the 5 merely to preserve some notion of "equal treatment".

However, it is exceedingly difficult to determine cost differentials among all emittors, and it is also difficult and expensive to monitor a large number of emittors. Hence, a uniform reduction of discharges across all emittors may minimize the sum of abatement, monitoring and enforcement costs.

One of the disadvantages of a standards approach is that once each emittor has reached the allowable level of discharges there is no further incentive to reduce dumping even more. This means that once new firms begin to enter an area and discharge residuals--or existing firms wish to increase production (and hence, in all likelihood, dumping)--the entire allocation arrangement must be revised. In short, there is very little excess capacity in the system to allow for new firms and output. It would, of course, be possible to design the initial allocation with this excess capacity in, but then current dischargers will argue that they are having to carry the abatement burden for unknown future emittors.

Economists tend to favor a system of effluent charges on units of emissions, with the fee per unit varying depending on the level of offsite damages produced. The advantage of this system is that the fee serves as a constant reminder to firms that it might be cheaper to adopt less polluting techniques, or to install in-plant treatment facilities. Another example is that this fee would become incorporated into the cost structure of the firm (industry) and would then be passed on to its consumers. This insures that consumers of polluting products are more nearly paying the social costs of the production of said products. Without this factor in the product price, consumers of high-residuals (highly polluting) commodities are obtaining the product at an artificially low price; it is artificially low because a valuable environmental service--waste

DISPOSAL--IS OBTAINED FREE OF CHARGE. OR, TO PUT IT ANOTHER WAY, THOSE WHO PREFER A CLEAN LAKE ARE NOW MADE TO BEAR SOME OF THE COSTS--IN TERMS OF LOWER WATER QUALITY--OF PRODUCING THE POLLUTING GOODS AND SERVICES.

AS INDICATED EARLIER, THE MAJOR DIFFICULTY WITH THE FEE APPROACH IS THAT IT IS BASED UPON AN ESTIMATE OF THE DAMAGES ARISING FROM POLLUTION; THIS RELATIONSHIP IS NOT AT ALL EASY TO DETERMINE. AND, THIS IS PARTICULARLY THE CASE WHERE IRREVERSIBILITIES[5] ARE PRESENT SUCH THAT FUTURE GENERATIONS WILL BEAR SOME OF THE DAMAGES. ALSO, IF THE DEMAND FOR A PARTICULAR POLLUTING PRODUCT SUDDENLY INCREASES, THE RESULTING PRICE INCREASE COULD LOOM SO LARGE WITH RESPECT TO THE EFFLUENT FEE PAID BY THE FIRM THAT IT WOULD MERELY INCREASE ITS PRODUCTION SIGNIFICANTLY (AS WELL AS ITS DISCHARGES) AND GLADLY PAY THE FEE. THE MONITORING AND ENFORCEMENT COSTS OF AN EFFLUENT CHARGE ARE SIGNIFICANT, AND MUCH MORE SUBSTANTIAL THAN MANY OF ITS ADVOCATES WOULD LIKE TO ADMIT.

THE FINAL OPTION FOR DEALING WITH DISCHARGES IS REFERRED TO AS THE STANDARDS-CHARGES APPROACH AND, AS THE NAME IMPLIES, IT INVOLVES A COMBINATION OF THE TWO PREVIOUS POLICIES. HERE, AN AMBIENT WATER QUALITY STANDARD IS ADOPTED AND A SET OF CHARGES IS THEN DERIVED FOR THE PRIVATE SECTOR'S USE OF SOCIALLY OWNED RESOURCES (THE ENVIRONMENT). DUMPING IS THEN PERMITTED IN CLOSE ACCORD WITH PRESENT-DAY TECHNOLOGY WHILE STILL MEETING THE STANDARD. THE DIFFERENCE FROM THE EFFLUENT FEE IS THAT NO EFFORT IS EXPENDED TO DETERMINE TOTAL (OR MARGINAL) SOCIAL DAMAGES RESULTING FROM DISCHARGES. HERE ONE HAS THE ASSURANCE THAT WATER QUALITY WILL NEVER FALL BELOW SOME MINIMUM--EVEN IF THE DEMAND FOR SOME POLLUTING PRODUCTS INCREASES SIGNIFICANTLY. ONE ALSO HAS THE ADVANTAGE THAT THE FEE SERVES AS A CONSTANT REMINDER TO INDUSTRY THAT THERE MAY BE CHEAPER OPTIONS SUCH AS TECHNOLOGICAL CHANGE OR IN-PLANT TREATMENT. WITH A FEE, A FIRM WILL REDUCE EMISSIONS UNTIL THE MARGINAL COST OF FURTHER REDUCTIONS IS EQUAL TO THE FEE (TAX). SINCE THE FEE IS THE SAME TO ALL FIRMS, EACH WILL BE CUTTING BACK TO THIS SAME POINT--WHICH MEANS THAT WE WILL ACHIEVE AN IMPORTANT ECONOMIC RESULT. THAT IS, THE LEAST-COST REDUCTION IN POLLUTION OVER A NUMBER OF DISCHARGERS ALL WITH DIFFERENT COSTS OF ABATEMENT. UNDER THIS SYSTEM SOME WILL CUT BACK EMISSIONS BY 10 PERCENT, SOME BY 20 PERCENT, SOME BY 25 PERCENT, ETC. BUT THE IMPORTANT POINT IS THAT THEY WILL ALL CUT BACK UNTIL THE MARGINAL COST OF DOING SO (FOR THEM) IS JUST EQUAL TO THE FEE (WHICH IS THE SAME FOR ALL). THIS WILL RESULT IN AN AGGREGATE REDUCTION IN EMISSIONS AT A LOWER COST THAN IF EACH FIRM HAD TO REDUCE DISCHARGES BY THE SAME PERCENTAGE.

WHO BENEFITS FROM A CLEANER LAKE?

WITHOUT BECOMING INVOLVED IN THE DETAILS OF CURRENT POLLUTANTS IN THE LAKE AND THE BENEFITS WHICH WILL RESULT FROM THEIR REDUCTION, IT WILL STILL BE POSSIBLE TO DISCUSS, IN A GENERAL SENSE, THE BENEFITS FROM A CLEANER LAKE. RECALL FROM ABOVE THAT THE PRECISE ASSIGNMENT OF ECONOMIC VALUE TO REDUCED POLLUTION IS MOST DIFFICULT. BUT WE CAN, NONETHELESS, PROVIDE SOME INSIGHTS INTO HOW THE ECONOMIST MIGHT BEGIN TO HELP POLICY MAKERS TO UNDERSTAND THE BENEFITS OF CLEANER WATER IN LAKE MICHIGAN.

THE FIRST STEP IN THIS PROCESS WOULD BE TO CLASSIFY THE USERS OF THE LAKE INTO THOSE WHO "USE" THE WATER IN THE LAKE VERSUS THOSE WHO REMOVE THE WATER PRIOR TO ITS DIRECT USE.[6] SOME EXAMPLES OF THE FORMER GROUP WOULD BE RECREATIONISTS AND THOSE ENGAGED IN COMMERCIAL FISHING. EXAMPLES OF THE LATTER GROUP WOULD BE CITIES AND VARIOUS INDUSTRIES WHO NEED WATER FOR VARIOUS CONSUMPTIVE USES.

CONSIDER THE FIRST CLASS OF USERS--THOSE WHO DERIVE BENEFICIAL USE OF THE WATER IN THE LAKE. TO THE EXTENT THAT CLEANER WATER INCREASES THE PRODUCTIVITY OF THE LAKE'S FISHERIES, THEN THOSE ENGAGED IN COMMERCIAL FISHING WILL CLEARLY BENEFIT FROM A CLEANER LAKE. SIMILARLY THOSE ENGAGED IN RECREATIONAL PURSUITS SUCH AS FISHING, SWIMMING, BOATING AND DIVING WILL BENEFIT. IN ADDITION TO THESE READILY IDENTIFIABLE USERS, THERE IS A LARGE (THOUGH PRACTICALLY INDETERMINATE) GROUP OF PEOPLE FOR WHOM A CLEANER LAKE HOLDS SOME VALUE, "AN EXISTENCE VALUE", EVEN THOUGH THEY WILL NEVER MAKE DIRECT USE OF IT. AN "EXISTENCE VALUE" OCCURS WHEN INDIVIDUALS PLACE SOME VALUE ON THE VERY FACT THAT THEY KNOW THAT LAKE MICHIGAN IS CLEANER THAN IT USED TO BE (OR THEY SUFFER A LOSS OF SATISFACTION KNOWING THAT IT IS POLLUTED, EVEN THOUGH THEY WILL NEVER SWIM IN IT, NEVER BOAT IN IT, NEVER FISH IN IT, AND NEVER EVEN SEE IT). IT HAS VALUE TO THEM IN ITS IMPROVED STATE EVEN THOUGH THEY WILL NEVER BE AMONG ITS DIRECT "USERS".

THERE IS ANOTHER SUBSET OF INDIVIDUALS WHO DERIVE SATISFACTION FROM A CLEANER LAKE--THOSE WHO DO NOT USE THE LAKE NOW, BUT WOULD LIKE TO HAVE THE OPTION OF DOING SO IN THE FUTURE. ECONOMISTS REFER TO THE VALUE THAT THEY PLACE ON THE CLEANER LAKE AS AN OPTION VALUE.

TO A LARGE EXTENT, EXISTENCE VALUES AND OPTION VALUES ARISE BECAUSE OF THE PRESENCE OF IRREVERSIBILITIES. OUR USE OF THE NATURAL ENVIRONMENT HAS BOTH SHORT-TERM AND LONG-TERM IMPLICATIONS. IF A MUNICIPAL SEWAGE PLANT DISCHARGES EFFLUENT WITH HIGH PHOSPHOROUS RESIDUES INTO LAKE MICHIGAN, THERE MIGHT BE A BUILD-UP OF ALGAE IN THE NEAR-SHORE AREA. IF THE PLANT CEASES OPERATION, IT MIGHT

NOT BE TOO LONG UNTIL THE ALGAE GOES AWAY, AND SO THE NUISANCE. BUT ASSUME THAT THE DISCHARGE TAKES PLACE OVER A VERY LONG TIME AND IN SUCH QUANTITIES THAT LARGE QUANTITIES OF ALGAE ARE NOURISHED. IF THE PROBLEM IS SUFFICIENTLY WIDESPREAD, IT IS POSSIBLE THAT THE DECOMPOSITION OF ALGAE IN THE LATE SUMMER COULD DEPLETE THE OXYGEN CONTENT OF THE WATER BODY TO A POINT WHERE ALL FISH LIFE WOULD PERISH. IF A SPECIES OF FISH IS ELIMINATED FROM THE LAKE THEN AN IRREVERSIBLE IMPACT HAS RESULTED AND--UNLESS RESTOCKING IS POSSIBLE--A CHANGE HAS OCCURRED WHICH CANNOT BE RECTIFIED. IF THE SPECIES OF FISH IS OF PARTICULAR VALUE, THEN THERE IS A LOSS OF EXISTENCE VALUE AND OF OPTION VALUE.

IT IS ALSO IMPORTANT TO POINT OUT HERE THAT THE ECOLOGICAL INTERDEPENDENCE OF PLANT AND ANIMAL SPECIES IN THE LAKE MEANS THAT IT IS VERY DANGEROUS TO BE CONCERNED WITH ONLY THOSE FISH FOR WHICH THERE IS SOME DIRECT AND CURRENT USE BY HUMANS. ECONOMISTS ARE SOMETIMES THOUGHT TO BE INTERESTED IN ONLY THOSE THINGS TO WHICH DOLLAR VALUE CAN BE ATTACHED--OR WHICH HAVE A CLEAR HUMAN SIGNIFICANCE. THIS IS NOT AN ACCURATE DEPICTION OF ECONOMIC CONCEPTS; ECONOMISTS FEEL MOST COMFORTABLE WHEN WORKING WITH THINGS FOR WHICH TANGIBLE VALUES HAVE BEEN EXPRESSED EITHER IN THE MARKET OR THROUGH THE POLITICAL PROCESS. BUT THE PRESSURE TO ATTACH DOLLAR VALUES TO SO-CALLED "INTANGIBLES" IS OFTEN GREATEST FROM NON-ECONOMISTS.

RETURNING THEN TO OUR TWO-PART CLASSIFICATION SCHEME, THE INCREASED BENEFITS TO THOSE WHO MAKE USE OF THE WATER IN THE LAKE WOULD BE REFLECTED IN: (1) THEIR INCREASED SATISFACTION; (2) THE NEW USERS WHO NOW PARTAKE OF THE CLEANER WATER; AND (3) THE HIGHER INCOME OF, FOR INSTANCE, THE COMMERCIAL FISHERMEN WHOSE CATCH HAS INCREASED BECAUSE OF THE PURER WATER. NOTICE THAT WE HAVE TWO CLASSES OF BENEFITS HERE, SOME OF WHICH ENTAIL INCREASED "SATISFACTION" AND SOME WHICH ENTAIL INCREASED INCOME (FROM INCREASED CATCH). THIS IS OFTEN RATHER UNSETTLING TO POLICY MAKERS WHO ARE FACED WITH A KNOWN COST OF CLEANING UP THE LAKE, AND TWO TYPES OF BENEFITS FROM THOSE EXPENDITURES: (1) INCREASED INCOME TO FISHERMAN; AND (2) INCREASED SATISFACTION TO RECREATIONISTS. IF A BENEFIT-COST ANALYSIS IS DESIRED IT IS IMPOSSIBLE TO COMPARE DIRECTLY THIS SECOND CATEGORY OF BENEFICIAL EFFECTS WITH THE KNOWN CLEAN-UP COSTS. THOSE OPPOSED TO EFFORTS TO CLEAN UP MIGHT BE TEMPTED TO DOWNPLAY THOSE BENEFICIAL EFFECTS WHICH CANNOT BE QUANTIFIED IN DOLLAR TERMS, AND HENCE THE CHOICE MIGHT BE BASED ON THE KNOWN CLEANUP COSTS AND ON THE BENEFITS FROM INCREASED INCOME TO FISHERMEN. THIS INCOMPLETE BENEFIT-COST CALCULATION WOULD BIAS DECISIONS AGAINST CLEANING UP THE LAKE.

To overcome this bias, economists have attempted to estimate the monetary value of the increased satisfaction from a cleaner Lake by inquiring as to how much people would be willing to pay for the cleaner water. This attempt to assign monetary values to increased satisfaction is subject to some criticism. It must be recognized, however, that policy makers often demand to know what they are obtaining for the known expenditure of public monies to clean up the Lake, and hence such monetary figures--as rough as they may be--can be of some assistance. Perhaps it would be easier if the decision process did not require such apparent "precision" and could result in action to clean up a Lake based on two kinds of information--increased economic benefits, and increased subjective value of the Lake to all users for which monetary figures are not possible to estimate.

Let's turn to the second group of users--those who remove water from the Lake for use. It is often easier to estimate the monetary value of the benefits derived by this group than it is for others. Consider a firm which relies on cool water from the Lake for some process and returns it to the Lake at approximately the same temperature (thermal pollution is not present). If, however, a thermal polluter would locate near the inlet of this firm then it would become necessary for the firm to construct and operate a cooling facility to lower the water temperature to its original level before it could be used. Here, the benefits to this firm of lowered pollution (thermal in this case) would be the costs saved by not having to build and operate the cooling facility.

Consider another example. Assume that a food processor is located on the shore of Lake Michigan and withdraws a certain amount of water for washing and packing. Further assume that it does not discharge any effluent to the lake. As the quality of Lake water deteriorates, it becomes necessary for the processor to spend increasing amounts of money to treat the water prior to its use. A program to clean up the lake would result in cost savings to the food processor, and these savings constitute the benefits of a cleaner lake. If we imagine a large number of similarly affected users of Lake water, then the total benefits in this general class of users would be the aggregate cost savings of all such firms.

To conclude this discussion of the benefits of cleaner water we must introduce an economic concept of great importance in environmental quality matters. A public good is something produced for which one person's enjoyment does not diminish that which is available to be enjoyed by others; there is no rivalry in consumption. Consider a lighthouse. The use of the beam from the lighthouse by one ship to reckon its position in no way diminishes

THE AMOUNT OF INFORMATION AVAILABLE FOR OTHER SHIPS. WHILE THE INFORMATION TRANSMITTED IS THE SAME, THE VALUE OF THAT INFORMATION MIGHT BE QUITE DIFFERENT. IMAGINE TWO SHIPS, ONE CARRYING A FULL CARGO OF THE FINEST FRENCH WINES TO NEW YORK RESTAURANTS, THE OTHER ONE RETURNING EMPTY FROM HAULING CARGO TO LONDON. THE SOCIAL COST OF THESE TWO SHIPS SINKING IN THE ABSENCE OF THE INFORMATION IS OBVIOUSLY QUITE DIFFERENT, EVEN THOUGH THEY BOTH USE THE SAME INFORMATION FROM THE LIGHTHOUSE.

TURNING NOW TO OUR DISCUSSION OF WATER QUALITY, IT TOO HAS THE CHARACTERISTIC OF A PUBLIC GOOD. IF WATER IS SERIOUSLY POLLUTED, ALL CITIZENS ARE AFFECTED, ALTHOUGH EACH INDIVIDUAL NEED NOT BE SIMILARLY INCONVENIENCED. SIMILARLY, WHEN THE LAKE'S WATER QUALITY IS IMPROVED, MY INCREASED SATISFACTION FROM THAT FACT DOES NOT DIMINISH THE SATISFACTION AVAILABLE FOR OTHERS. COMPARE THIS TO PRIVATE GOODS--THOSE THINGS THAT NORMALLY PASS THROUGH MARKETS. IF I PURCHASE A STUNNING RENOIR, I AUTOMATICALLY DEPRIVE ALL OTHERS FROM THE BENEFITS OF THAT ITEM--UNLESS, OF COURSE, I CHOOSE TO DISPLAY IT SOMEWHERE (PERHAPS EVEN COLLECT A FEE). SIMILARLY, IF I PURCHASE A NICE SWEATER I DEPRIVE SOMEONE ELSE FROM ACQUIRING THAT PARTICULAR ITEM. PRIVATE GOODS ARE RIVALROUS IN CONSUMPTION.

THE PUBLIC-GOODS ASPECT OF IMPROVED WATER QUALITY RAISES SOME PROBLEMS IN TERMS OF ESTIMATING THE BENEFITS OF A CLEANER LAKE AND ALSO IN ASSESSING THE BENEFICIARIES OF A CLEANER LAKE. LET'S CONSIDER THE BENEFIT SIDE FOR THE MOMENT.

WHEN INDIVIDUALS PURCHASE ORDINARY (PRIVATE) GOODS, THEY READILY REVEAL THEIR WILLINGNESS TO PAY FOR THE GOODS IN THE ACT OF PURCHASE. WHEN YOU BUY A LOAF OF BREAD, YOU REVEAL THE EXTENT OF YOUR PREFERENCE FOR THE COMMODITY BY YOUR WILLINGNESS TO PART WITH SO MUCH MONEY. UNLESS YOU SUSPECT THAT THE MERCHANT WOULD ENGAGE IN BARGAINING, THERE IS LITTLE INCENTIVE FOR YOU TO ATTEMPT TO CONCEAL YOUR TRUE WILLINGNESS TO PAY. BUT FOR A GOOD SUCH AS IMPROVED WATER QUALITY, THE DECISION IS NOT QUITE SO STRAIGHTFORWARD. FIRST, SUCH GOODS ARE NOT NORMALLY HANDLED IN CONVENTIONAL MARKETS, SO YOU HAVE LITTLE BASIS FOR ESTIMATING ITS WORTH TO YOU. SECONDLY, IF YOU DO DECIDE TO ACTUALLY BECOME INVOLVED IN DIRECT USE OF THE IMPROVED WATER QUALITY--THROUGH RECREATION--THE QUALITY OF THE EXPERIENCE MAY BE MATERIALLY AFFECTED BY THE NUMBER OF OTHERS WHO ALSO CHOOSE TO RECREATE AT THAT SAME TIME. THUS, WHILE WE CONSIDER IMPROVED WATER QUALITY TO BE A PUBLIC GOOD, CROWDING MAY EXIST IF YOU ATTEMPT TO USE THE LAKE, AND HENCE YOUR ESTIMATE OF ITS NEW CLEANER STATUS TO YOU MAY BE AFFECTED.

BUT THE MOST SERIOUS DIFFICULTY WHICH ARISES FROM THE PUBLIC GOOD NATURE OF IMPROVED WATER QUALITY IS THAT BENEFICIARIES HAVE AN INCENTIVE TO CONCEAL THEIR TRUE EVALUATION OF THE IMPROVEMENT, AND EMITTORS HAVE THE SAME INCENTIVE. IF BENEFICIARIES BELIEVE THAT THEY WILL NOT HAVE TO PAY FOR ENHANCED QUALITY THEY MIGHT OVERSTATE THEIR

PREFERENCE. IF THEY FEAR THEY MIGHT HAVE TO PAY THEN THEY HAVE AN INCENTIVE TO UNDERSTATE THEIR PREFERENCE FOR CLEANER WATER. WITH ALL OF THESE CONFLICTING SIGNALS ABOUT THE VALUE (BENEFITS) OF IMPROVED WATER QUALITY, IT IS LITTLE WONDER THAT POLICY FORMULATION IS DIFFICULT.

HENCE, THE PUBLIC-GOODS ASPECT OF IMPROVED WATER QUALITY DOES NOT DETRACT FROM THE EXISTENCE OF BENEFITS FROM CLEANER WATER, BUT IT OBVIOUSLY COMPLICATES THE PRECISE DETERMINATION OF THEIR MAGNITUDE. THIS FACT MEANS THAT ECONOMICS CAN BE OF SOME ASSISTANCE IN DECIDING UPON THE IDEAL LEVEL OF POLLUTION ABATEMENT, BUT THAT THE ULTIMATE DECISION IS A SOCIETAL VALUE JUDGMENT.

WHO WILL PAY FOR CLEANER WATER?

WE HAVE TALKED OF THE BENEFITS AND THE BENEFICIARIES OF A CLEANER LAKE, AND IT IS NOW TIME TO DISCUSS THOSE FOR WHOM A CLEANER LAKE WILL MEAN SOME LOSS OF INCOME OR SATISFACTION. IT SEEMS SAFE TO ASSUME THAT FEW INDIVIDUALS--CURMUDGEONS ASIDE--WOULD RESENT AN IMPROVEMENT IN WATER QUALITY UNLESS THEY STOOD TO LOSE SOMETHING OF PSYCHIC OR FINANCIAL VALUE. HENCE WE CAN RESTRICT OUR DISCUSSION TO THOSE INSTANCES IN WHICH IT IS POSSIBLE TO ASSIGN A MONETARY VALUE TO THE CHANGES THAT A CLEANER LAKE MIGHT IMPLY. EXAMPLES WOULD BE HIGHER TREATMENT COSTS TO DISCHARGERS; HIGHER TAXES TO FINANCE LARGER MUNICIPAL WASTE TREATMENT FACILITIES; ADJUSTMENT COSTS FOR TECHNOLOGICAL CHANGE TO LESS-POLLUTING PROCESSES; REDUCED JOBS BECAUSE OF REDUCTIONS IN TOTAL OUTPUT OF FIRMS (OR PLANT CLOSINGS); AND IN GENERAL A REDUCED PROFITABILITY OF BUSINESSES BECAUSE A FORMERLY FREE FACTOR OF PRODUCTION (WASTE DISPOSAL SERVICES) IS NOW LESS AVAILABLE--OR SIMPLY MORE COSTLY.

THERE IS NOT SPACE HERE TO DO JUSTICE TO ALL THE FACTORS WHICH REQUIRE DISCUSSION AND HENCE WE WILL TALK IN RATHER GENERAL TERMS ABOUT WHO MIGHT (OR SHOULD) PAY FOR CLEANER WATER IN LAKE MICHIGAN. AS INDICATED ABOVE, THIS DISCUSSION CANNOT BE CONDUCTED WITHOUT RECOGNIZING THE CRUCIAL ROLE OF THE PRESUMPTIVE PROPERTY RIGHTS IN THE ENVIRONMENT, AND THE IMPORTANCE OF OUR STARTING POINT.

THERE IS A NOTION IN ECONOMICS WHICH SAYS THAT THE BENEFICIARIES OF SOMETHING SHOULD SOMEHOW CONTRIBUTE TOWARD THE AMORTIZATION AND "OPERATING" COSTS OF THAT THING, OTHERWISE THE BENEFICIARIES WILL BE TEMPTED TO DESIRE TOO MUCH OF THE FREE GOOD. IF THIS ARGUMENT IS APPLIED TO IMPROVING WATER QUALITY IN LAKE MICHIGAN, THEN SOME MIGHT ARGUE THAT THOSE ADVOCATING CLEANER WATER SHOULD PAY FOR IT SINCE IT IS THEIR "FAULT" THAT THIS PRESSURE IS BEING BROUGHT ON CURRENT DISCHARGERS. UNDER THIS SCHEME RECREATIONISTS WOULD BE REQUIRED TO PAY A FEE FOR DAILY USE OF THE LAKE WITH SUCH A FEE GOING TO THOSE WHO HAVE BEEN INCONVENIENCED BY THE NEW "RULES OF THE GAME". IF INDUSTRY IS REQUIRED TO INSTALL TREATMENT FACILITIES THEN THIS FEE WOULD GO TO INDUSTRY TO OFF-

SET THE COSTS OF THIS NEW EQUIPMENT. A VARIATION ON THIS THEME IS TO GRANT INDUSTRY TAX CONCESSIONS FOR NECESSARY INVESTMENTS IN THE INTEREST OF IMPROVED WATER QUALITY. THE CONCESSION RESULTS IN REDUCED TAX LIABILITIES FOR INDUSTRY AND IF THE REVENUE MUST BE RECOVERED IN ANOTHER MANNER THEN THE GENERAL PUBLIC WILL PICK UP THE BALANCE. AND, SINCE IT IS THE "GENERAL PUBLIC" WHICH WILL BENEFIT FROM IMPROVED WATER QUALITY THEN THE "BENEFICIARY-PAYS" PRINCIPLE IS APPROXIMATELY FOLLOWED.

THE TROUBLE WITH THIS APPROACH IN THE ENVIRONMENTAL QUALITY AREA IS THAT IT IS PRESUMPTIVE OF THE PROPERTY RIGHTS SITUATION IN THE STATUS QUO. WE TALKED EARLIER ABOUT ALTERNATIVE ASSIGNMENTS OF PROPERTY RIGHTS IN ENVIRONMENTAL RESOURCES AND THE INFLUENCE THAT SUCH ASSIGNMENTS WILL HAVE ON POLICY. HERE WE SEE THAT THE ISSUE IS COMPETITION BETWEEN TWO USERS FOR THE VALUABLE SERVICES OF THE ENVIRONMENT; INDUSTRY AND MUNICIPALITIES WANT THE WASTE-DISPOSAL SERVICES OF THE LAKE, THE "PUBLIC" WANTS THE AMENITY SERVICES OF THE LAKE. IT REQUIRES A DEFINITE ETHICAL JUDGMENT TO ARGUE THAT THOSE WHO BENEFIT FROM CLEANER WATER ARE BOUND TO PAY FOR THAT IMPROVED WATER QUALITY. CONSIDER THE SITUATION WHERE "ENVIRONMENTALISTS GOT THERE FIRST" AND INDUSTRY AND MUNICIPALITIES WERE THE LAKE COMERS. NOW THEY DESIRE TO USE THE VALUABLE SERVICES OF THE LAKE FOR WASTE DISPOSAL PURPOSES AND THE ISSUE IS ONE OF SHOULD THEY PAY--AND HOW MUCH--AS BENEFICIARIES OF THE CONTRIBUTION MADE BY THE LAKE TO THE PROFITABILITY OF THEIR ENDEAVOR?

WE CAN NOW ELABORATE ON A DISCUSSION INTRODUCED BRIEFLY BEFORE. ANY ECONOMIC ENTERPRISE COMBINES A VARIETY OF INPUTS (FACTORS OF PRODUCTION) TO CREATE ITS PRODUCT. IT PURCHASES LAND (OR LEASES IT), IT BUYS CERTAIN CAPITAL EQUIPMENT, AND IT HIRES LABOR. ALL OF THESE INPUTS CONTRIBUTE TO ITS FINAL PRODUCT. IT MAY ALSO PURCHASE SPECIALIZED EQUIPMENT TO TREAT THE BY-PRODUCTS OF ITS PRODUCTION PROCESSES. IF NO SUCH EQUIPMENT IS AVAILABLE--OR IF THE FIRM HAS AN ALTERNATIVE WHICH IS CHEAPER--IT WILL GET RID OF THESE BY-PRODUCTS BY DISCHARGING THEM INTO THE AIR, OR DUMPING THEM INTO A RIVER OR LAKE, OR HAULING THEM TO A LANDFILL SITE. IF IT PAYS NOTHING FOR THE USE OF WATER-BASED DISPOSAL SYSTEMS, IT IS RECEIVING A VALUABLE SERVICE AT ZERO COST; ECONOMIC THEORY TELLS US THAT THE FIRM WILL THEREFORE USE MORE OF THAT SERVICE THAN IF A FEE WERE PAID. THAT IS, FREE GOODS TEND TO BE EXCESSIVELY USED.

SO THE EFFLUENT FEE DISCUSSED PREVIOUSLY IS CONSISTENT WITH THE ECONOMIC PRINCIPLE THAT VALUABLE INPUTS BE PRICED ON THE BASIS OF THEIR RELATIVE CONTRIBUTION TO THE VALUE OF THE FINAL PRODUCT. ONE WAY OF ESTIMATING A POSSIBLE PRICE FOR THIS SERVICE WOULD BE TO INQUIRE WHAT THE COST MIGHT BE OF THE NEXT CHEAPEST ALTERNATIVE. THAT IS, IF THE LAKE WERE NOT AVAILABLE HOW MUCH WOULD IT COST THE FIRM PER UNIT OF PROCESSED BY-PRODUCT? THIS

WOULD BE ONE ESTIMATE OF THE VALUE OF THE SERVICE PROVIDED BY THE WATER.

PURSUING THIS ARGUMENT A LITTLE FURTHER, WE HAVE SEEN EARLIER HOW THE CONSUMERS OF PRODUCTS WITH NOXIOUS OR UNDESIRABLE BY-PRODUCTS ARE GETTING A BARGAIN IF THE PRICE OF THOSE PRODUCTS DOES NOT REFLECT THE FULL SOCIAL COST OF THEIR MANUFACTURE. IF IT REQUIRES VALUABLE ENVIRONMENTAL SERVICES TO PRODUCE PINK TOILET TISSUE AND YET PAPER COMPANIES PAY NOTHING FOR THE WASTE-DISPOSAL SERVICES OF THE RIVER, THEN ENVIRONMENTALISTS ARE SUBSIDIZING THE MANUFACTURE OF THIS PARTICULAR PRODUCT. THE SAME REASONING APPLIES TO A VARIETY OF OTHER POLLUTING PRODUCTS. A FEE ON THE MANUFACTURE OF SAID PRODUCTS TO REFLECT THIS ENVIRONMENTAL SERVICE SHOULD BE PASSED ON TO CONSUMERS SO THAT THEY MORE NEARLY PAY THE APPROPRIATE COST FOR THEIR CONSUMPTION.

THUS THE ISSUE OF WHO PAYS FOR CLEANER WATER IN LAKE MICHIGAN IS COMPLICATED BY MANY FACTORS--AS WELL AS BY THE PARTICULAR POLICY INSTRUMENT CHOSEN. IF FIRMS ARE SUBSIDIZED TO CLEAN UP THEIR DISCHARGES, THEN WE ALL PAY IN THE FORM OF REDUCED TAX REVENUE OR INCREASED LEVIES TO REMEDY THE SHORTFALL. HERE, CONSUMERS OF THE PRODUCTS CONTINUE TO PAY A PRICE BELOW THE FULL SOCIAL COST OF PRODUCTION. IF ONLY DIRECT USERS OF THE LAKE PAY A FEE TO OFFSET THE ECONOMIC COSTS TO INDUSTRY OF CLEANING UP THEN NON-RECREATORS WHO BENEFIT FROM A CLEANER LAKE MICHIGAN ARE "FREE RIDERS" ON THOSE WHO DO PAY. IF ONLY THE WELL-TO-DO FEEL BENEFITTED FROM A CLEANER LAKE, YET THE PROGRAM IS FINANCED OUT OF TAX REVENUES THEN THE POOR PAY AND RECEIVE FEW, IF ANY, BENEFITS. IF SOME INDIVIDUALS IN MANUFACTURING LOSE JOBS BECAUSE A PLANT MUST CLOSE DOWN THEN THEY PAY. WE MUST BE CAREFUL WITH GENERALIZATIONS, HOWEVER, FOR THIS IS A VERY COMPLEX MATTER. IT HAS BECOME FASHIONABLE FOR COMPANIES TO ATTRIBUTE THE CLOSING OF A PLANT TO ENVIRONMENTAL RESTRICTIONS, WHEN IN FACT THERE IS A VARIETY OF REASONS RANGING FROM A DECREASE IN DEMAND FOR THE PRODUCT TO OLD INEFFICIENT PLANTS THAT WERE TO BE CLOSED ANYWAY. IT IS CONVENIENT FOR A COMPANY TO BLAME SUCH THINGS ON ENVIRONMENTALISTS, BUT THE REAL REASONS ARE USUALLY MUCH MORE COMPLICATED.

IN PRACTICE, IT IS A COMBINATION OF INDIVIDUALS AND GROUPS WHO PAY FOR CLEANER WATER. INDUSTRY PAYS IN THE FORM OF INCREASED INVESTMENT IN POLLUTION CONTROL EQUIPMENT. SOME WORKERS MAY PAY IN TERMS OF LAYOFFS FROM PLANTS TOO OLD TO BE MODIFIED. SOME MUNICIPALITIES MAY HAVE TO LEVY HIGHER TAXES TO PAY FOR SEWAGE TREATMENT PLANTS--AND HENCE THE GENERAL PUBLIC PAYS. FINALLY, CONSUMERS OF THOSE PRODUCTS WHICH ARE THE MOST DEGRADING OF THE ENVIRONMENT PAY IN THE FORM OF HIGHER PRODUCT PRICES. AND TAXPAYERS ALSO PAY IN GENERAL FOR THE BUREAUCRACY WHICH IS NECESSARY TO WATCH OVER FIRMS AND MUNICIPALITIES WHICH HAVE--HISTORICALLY--SHOWN A GREAT PROPENSITY FOR FOOT DRAGGING AND EVASIVE ACTION.

BUT, IT IS PROBABLY FITTING THAT EACH OF US PAY A LITTLE. AFTER ALL, WHEN WE RECOGNIZE THAT POLLUTION IS A RESULT OF A LOT OF THINGS--TECHNOLOGY, INCREASED POPULATION DENSITY, CHANGING TASTES AND PREFERENCES--IT IS ONLY REASONABLE TO CONCLUDE THAT NO SINGLE GROUP OF INDIVIDUALS NEED CARRY FULL LIABILITY. SIMILARLY, SINCE MANY DIFFERENT INDIVIDUALS WILL BENEFIT, THE FACT THAT EACH WILL PAY A LITTLE ALSO SEEMS MORE EQUITABLE. WHEN ALL IS SAID AND DONE, WE MUST REALIZE THAT EACH OF US FULFILLS SEVERAL ROLES; THERE ARE NOT MERELY POLLUTERS AND ENVIRONMENTALISTS. MANAGERS OF PAPER MILLS ALSO FISH AND WATER SKI, SO DO SEWAGE TREATMENT PLANT OPERATORS; FARMERS ENJOY HAVING A CLEAR STREAM PASS THROUGH THEIR LAND. WE ALL BENEFIT IN SOME WAY FROM CLEAN WATER, JUST AS WE ALL BENEFIT FROM THOSE PRODUCTS THAT PRODUCE POLLUTION. WHO AMONG US USES NO PAPER, AUTOMOBILE, TIN CAN, CELLOPHANE, PHOSPHATE, ELECTRICITY, LAWN FERTILIZER?

AS WE MOVE TOWARD A RECOGNITION THAT OUR LAKES AND RIVERS HAVE USES OTHER THAN AS SEWERS, WE ALSO RECOGNIZE THAT A CHANGE IN THAT ASSUMPTION WILL AFFECT US ALL. EQUITY DEMANDS THAT WE ALL SHARE IN THE COST OF CHANGE.

SUMMARY

THE ECONOMIST IS INCLINED TO SEE POLLUTION IN LAKE MICHIGAN AS THE CULMINATION OF SEVERAL FACTORS: (1) INCREASING POPULATION CONCENTRATIONS NEAR THE WATER; (2) THE ADVENT OF POLLUTING TECHNOLOGY PRIMARILY THROUGH CHEMICALS AND HIGH TEMPERATURES; AND (3) CHANGING TASTES AND PREFERENCES WITH RESPECT TO WHAT SORT OF ENVIRONMENT WE WANT TO HAVE. THE ECONOMIST IS ALSO INCLINED TO SEE A SOLUTION BY CONCEPTUALIZING THE ENVIRONMENT AS PROVIDING SOME ENVIRONMENTAL SERVICES WHICH CAN BE UTILIZED WITHOUT THE GENERATION OF HARM. THE ECONOMICS OF LAKE QUALITY THEN CONCERNS THE ALLOCATION OF THESE ENVIRONMENTAL SERVICES TO ACHIEVE A CERTAIN LEVEL OF AMBIENT WATER QUALITY AT LEAST COST.

THIS VIEW DOES NOT DERIVE FROM ANY VALUE JUDGEMENT BY ECONOMISTS THAT POLLUTION OUGHT TO OCCUR--EVEN IN SMALL AMOUNTS. IT DERIVES, INSTEAD, FROM THE REALIZATION THAT TOTAL PROHIBITION OF ALL EMISSIONS INTO THE ENVIRONMENT (AIR OR WATER) MAY BE VERY EXPENSIVE. FOR TOXIC ELEMENTS SUCH PROHIBITIONS MAKE GOOD SENSE. BUT FOR A CLASS OF INDUSTRIALIZED AND MUNICIPAL EMISSIONS, IT MAKES ECONOMIC SENSE TO SEARCH FOR WAYS TO UTILIZE THE FREE EN-ENVIRONMENTAL SERVICES OF THE LAKE.

THE ECONOMICAL WAY TO IMPROVE WATER QUALITY IN LAKE MICHIGAN IS THROUGH A CONCERTED EFFORT TO REDUCE EMISSIONS VIA TECHNOLOGICAL CHANGE, AS WELL AS SOME "END-OF-PIPE" ABATEMENT. ECONOMICS CAN BE HELPFUL IN SEARCH FOR THE FEASIBLE OPTIONS UNDER BOTH OF THESE ALTERNATIVES.

THE DECISION AS TO HOW CLEAN THE SHOULD BECOME IS NOT AN ECONOMIC MATTER, ALTHOUGH THE DECISION WILL CERTAINLY HOLD ECONOMIC IMPLICATIONS. THE PROPER LEVEL

OF POLLUTION IS A SOCIAL CHOICE, TO BE ARRIVED AT IN A MANNER SIMILAR TO THE DECISION AS TO HOW MANY CHILDREN SHOULD RECEIVE SCHOOL LUNCHES (OR BREAKFASTS); HOW MANY MILES OF FREEWAYS WE OUGHT TO HAVE; AND HOW MANY SMALL TOWNS WILL BE DROPPED FROM SERVICE BY AMTRAK. ECONOMIC CONCEPTS SUCH AS OPTION VALUE, EXISTENCE VALUE, IRREVERSIBILITIES, PUBLIC GOODS, TRANSACTION COSTS, AND MARGINAL BENEFITS WILL BE EXTREMELY HELPFUL IN THE DEBATE. BUT ECONOMICS DOES NOT BEHOLD THE EASY ANSWER.

THE DIFFICULT VALUE JUDGEMENTS ENTER WHEN WE BEGIN TO ASK ABOUT WHO HOLDS THE "RIGHTS" TO THE WATER RESOURCE; IS IT INDUSTRY, RECREATIONISTS, OR CITIES? THE EASY ANSWER IS THAT WE ALL DO, BUT THAT DOES NOT HELP IN TERMS OF WHO OUGHT TO DECIDE ABOUT WATER QUALITY. BOTH SIDES TO THE DEBATE OF LESS POLLUTION VERSUS THE SAME LEVEL OF POLLUTION HAVE ESTIMATES OF THE HARM THAT WILL COME FROM LISTENING TO THE OTHER SIDE, AND ALSO OF THE BENEFITS WHICH WILL OCCUR BY LISTENING TO THEM. AND YET, GOOD SOLID ECONOMIC DATA ARE DIFFICULT TO OBTAIN. THIS FACT RENDERS BENEFIT-COST ANALYSIS CONCERNING THE "OPTIMAL" LEVEL OF POLLUTION (OR OF ABATEMENT) ALMOST MEANINGLESS. THE MORE FEASIBLE ROUTE IS TO DETERMINE A SOCIALLY ACCEPTABLE LEVEL OF POLLUTION WITHIN SPECIFIC JURISDICTIONS AND THEN TO ACHIEVE THAT GOAL BY THE CHEAPEST POSSIBLE MEANS. HERE, COST-EFFECTIVENESS ANALYSIS IS MORE PRACTICAL THAN IS BENEFIT-COST ANALYSIS.

LAKE ECONOMICS THEN, MEASUREMENT PROBLEMS ASIDE, INVOLVES THE DETERMINATION OF SOME LEVEL OF CONTINUED EMISSIONS THROUGH THE POLITICAL PROCESS, AND A SET OF POLICIES AND INSTITUTIONAL ARRANGEMENTS WHICH WILL RENDER THAT DECISION IN AN EFFICIENT MANNER. IT ALSO MEANS ECONOMIZING ON THE USE OF SCARCE FINANCIAL RESOURCES IN ENFORCEMENT AND ADMINISTRATIVE EFFORTS. BUT, MOST IMPORTANTLY, LAKE ECONOMICS MEANS RECOGNIZING THE DIVERGENCE BETWEEN PRIVATE INTERESTS AND PUBLIC INTERESTS. LETTING "PRIVATE ENTERPRISE WORK" IS A FINE POLICY AS LONG AS ALL ASPECTS OF THE ENDEAVOR ARE VALUABLE TO US. BUT WHEN PART OF THE OUTPUT OF SUCH ENTERPRISE IS ACTUALLY NON-MARKETABLE BY-PRODUCT, THEN THERE IS NO SUCH THING AS PRIVATE ENTERPRISE; IT IS ALL PUBLIC. SOME OF THE OUTPUT IS INDEED PRODUCED BY PRIVATELY OWNED FIRMS, AND SOME OF IT SURELY PASSES THROUGH A TRANSPORTATION/WHOLESALING/RETAILING SYSTEM THAT IS CLEARLY PRIVATELY OWNED. BUT AN IMPORTANT PART OF THE OUTPUT FROM THIS ACTIVITY IS DEFINITELY NON-PRIVATE--IT IS DISCHARGED INTO THE PUBLIC DOMAIN TO BE CARRIED AWAY SO THAT DISPOSAL COSTS CAN BE AVOIDED. THIS PRIVATE-PUBLIC ISSUE IS AT THE HEART OF THE ECONOMICS OF LAKE QUALITY.

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THE DECISION-MAKING PROCESS AND AGENCY INVOLVEMENT

IN THE CHAPTER ON ECONOMICS WE CONSIDERED DIFFERENTIAL COSTS AND BENEFITS RELATED TO WATER QUALITY. SORTING OUT THESE COSTS AND BENEFITS AND MAKING THE DIFFICULT CHOICES WHICH RESULT IN THEIR DISTRIBUTION ENTAILS A DECISION-MAKING PROCESS. THAT PROCESS OF TURNING INFORMATION AND IDEAS INTO ACTIONS IS A CONTINUAL PROCESS THAT TAKES PLACE IN MANY SETTINGS; IT ENGAGES THE ATTENTION OF MANY DIFFERENT ACTORS. THE PROCESS IS SOMETIMES RATIONAL, INVOLVING A TECHNICAL JUDGEMENT ON THE OPTIMALITY OF AN ACTION. BUT THE PROCESS AT OTHER TIMES IS CHARACTERIZED BY POLITICAL BARGAINING AND NEGOTIATION THAT OCCASIONALLY BECOMES FRENZIED. THE DIFFERENT STRANDS ARE WOVEN TOGETHER UNTIL WE HAVE POLICIES, UNTIL WE HAVE LAWS, UNTIL WE HAVE REGULATIONS, WHICH IN TURN ARE CONVERTED INTO PLANS AND PROGRAMS.

THIS SECTION WILL TRY TO PLACE SOME FRAMEWORK ON THE "BLOOMING, BUZZING CONFUSION." IN SO DOING IT WILL SIMPLIFY BEHAVIORS AND INTERRELATIONSHIPS WHICH ARE NEVER CUT AND DRIED. WE ARE MOVING AWAY FROM THE ASSURANCE OF SCIENTIFIC METHOD TO THE UNCERTAINTIES OF CHOICE. BUT WE ARE MOVING AS WELL INTO THE EXCITING ARENA WHERE SCIENTIFIC VISIONS CAN BE REALIZED IN FACT.

THIS CHAPTER WILL HAVE TWO PARTS. THE FIRST PART WILL DISCUSS DECISION-MAKING AS IT RELATES TO WATER QUALITY ISSUES. THE SECOND SECTION WILL IDENTIFY SOME OF THE CURRENT AGENCIES THAT ARE PRESENTLY RESPONSIBLE FOR DECISION-MAKING.

DECISION-MAKING

EVERYONE MAKES DECISIONS; THOSE WHO, IN SOME PHASE OF THEIR PROFESSIONAL LIVES, ADDRESS WATER QUALITY ISSUES--JOURNALISTS, BUSINESSMEN, LAWYERS, PLANNERS, CITIZENS--MAKE DECISIONS WHICH AFFECT THE LAKE. SURELY THE AMALGAM OF THE DECISIONS MADE BY THESE PEOPLE IN THEIR VARIOUS CAPACITIES, IF WELL-INFORMED, WILL LEAD TO IMPROVED LAKE QUALITY. BUT THE PROCESS OF TURNING THESE WELL-INFORMED AND, WE ASSUME, WELL-INTENTIONED INDIVIDUAL DECISIONS INTO SOME POLICY AND PROGRAM IS NOT A RANDOM PROCESS. IF IT WERE RANDOM THERE WOULD BE NO REASON TO DEVISE BETTER WAYS OF HANDLING INFORMATION, OF PLANNING FOR CHANGE, OR OF PRESSING FOR ACTION. THERE IS A STRUCTURE THROUGH WHICH INDIVIDUAL ACTIONS ARE SIFTED. AT ITS MOST BASIC LEVEL THIS STRUCTURE IS THE STRUCTURE OF THE GOVERNMENT ITSELF. BUT, AS WE SHALL SEE, THIS STRUCTURE ALSO INVOLVES THE WAY PEOPLE AND ORGANIZATIONS RELATE TO EACH OTHER AND TO HISTORICAL EVENTS.

136

INDIVIDUAL AND GROUP DECISIONS CAN BE TAKEN OUT OF THE REALM OF THE RANDOM BY THE USE OF TECHNIQUES OR METHODOLOGIES. JUST AS THE POLITICAL STRUCTURE PROVIDES A FRAMEWORK ONTO WHICH THE ACTIVITIES OF ORGANIZATIONS AND EVENTS CAN BE GRAFTED, SO THE METHODOLOGIES CAN GIVE A FRAMEWORK TO INDIVIDUAL DECISIONS, ALLOWING THE DECISION-MAKER TO CLARIFY HIS QUESTION AS WELL AS TO STRUCTURE SOME ANSWER. THESE METHODS, WHILE ENHANCING RATIONAL CHOICE BETWEEN TOUGH ALTERNATIVES, DO NOT NECESSARILY MOVE THE DECISION-MAKER CLOSER TO SOME ABSTRACT REALIZATION OF THE "RIGHT" ANSWER. INDEED, THE SHAPE OF THE STRUCTURE WILL INFLUENCE THE SHAPE OF THE ANSWER.

THE WORLD OF POLITICAL CHOICE AND CHANGE IS AT A MACRO-LEVEL OF ANALYSIS WHILE THE WORLD OF INDIVIDUAL CHOICE AND DECISION IS AT THE MICRO-LEVEL. INFORMATION ON THE DECISIONS MADE AT THE MACRO- AND MICRO-LEVELS FLOWS FAST AND FURIOUSLY BETWEEN THE TWO. INDIVIDUAL ANALYSIS BASED ON RATIONAL METHODOLOGY MAY BECOME PART OF A PROPOSAL THAT IS HAMMERED OUT IN THE POLITICAL ARENA. LIKEWISE, POLITICAL DECISIONS MADE AT THE MACRO-LEVEL MAY NEED TO BE TRANSLATED INTO STANDARDS, AND SUBSEQUENTLY INTO MEASURABLE CRITERIA, AND THESE STANDARDS AND CRITERIA CAN BE BETTER FORMULATED IF SUBJECTED TO THE RIGORS OF A MICRO-LEVEL DECISION-MAKING METHODOLOGY.

THIS SECTION, THEN, WILL DISCUSS THE MACRO-LEVEL STRUCTURES AND MICRO-LEVEL METHODOLOGIES.

WE BEGIN WITH THE SIMPLEST WAY OF LOOKING AT GOVERNMENTAL STRUCTURE: AS A FEDERAL SYSTEM WITH THREE GOVERNMENTAL LAYERS: NATIONAL, STATE AND LOCAL. WATER POLLUTION, AS SUCH, CANNOT BE SAID TO HAVE BEEN A MAJOR CONCERN OF ANY ONE OF THESE LAYERS UNTIL AFTER WORLD WAR II. GOVERNMENTS WERE CONCERNED PRIMARILY WITH NATIONAL EXPANSION AND THIS LAND'S SEEMINGLY INEXHAUSTIBLE RESOURCES. THE NATIONAL GOVERNMENT WAS PRINCIPALLY INTERESTED IN DEVELOPMENT. WHEN AN AREA BEGAN TO PROSPER, THE FEDERAL ROLE SEEMS TO HAVE DIMINISHED ACCORDINGLY. WHEN AN OUTMODED TECHNOLOGY COULD BE REPLACED BY A MORE EFFICIENT ONE IT WAS THE FEDERAL GOVERNMENT THAT HAD A HAND IN PROVIDING ASSISTANCE. FOR EXAMPLE, THE FEDERAL GOVERNMENT'S INTEREST IN CANALS CHANGED RAPIDLY TO AN INTEREST IN RAILROADS. DURING THE TIME OF RAPID DEVELOPMENT, WE ANTICIPATED THAT NATURAL PROCESSES WOULD CLEANSE OUR WATERS, OR WERE OBLIVIOUS TO THE CONSEQUENCES OF DEVELOPMENT. HOWEVER, AT THE LOCAL LEVEL IN THE UNITED STATES, AND MORE FULLY IN THE RAPIDLY INDUSTRIALIZING CITIES OF EUROPE, IT WAS EVIDENT THAT NATURAL PROCESSES WOULD NOT DEAL WITH THE RESULTANT HEALTH HAZARDS IN MUNICIPAL AREAS. WASTE DISPOSAL AND PROVISIONS FOR SANITATION AND A CLEAN WATER SUPPLY BECAME CENTRAL RESPONSIBILITIES AND FUNCTIONS OF THE MUNICIPALITIES, WHILE THE STATE WAS INVOLVED BY AND LARGE AS A REGULATOR THROUGH ITS GENERAL POLICE POWERS.

Example of Early Municipal Involvement: Chicago

The Lake has always been a source of water for the city of Chicago. Lake water was once sold by peddlars for 10 to 25 cents a barrel. The Chicago Hydraulic Company, with a 70 year Charter from the Legislature, began operations in 1842 with a pumping station and reservoir at the corner of Lake Street and Michigan Avenue. However, four-fifths of the population of 4500 still obtained water from the River or the water carts. The city took over the company ten years later. A Board of three Water Commissioners was given authority to borrow money and issue bonds and a new supply system was planned to serve a population that had grown during that decade by a factor of 10. A pumping station was built at Chicago Avenue and the Lake, and plans were made for a crib 600 feet from shore. The crib project was abandoned because of rough water and, consequently, water entered the system near the shoreline. The system was based on a population projection of 100,000 by 1860, but even before that date the actual population had exceeded 200,000.

During this period sewage was discharged either directly into the Lake or into the Chicago River, which at that time flowed into the Lake. Filters for the intake pipes were inadequate--newspapers reported that even fish found their way into the water pipes. It was clearly necessary to move the intake point beyond shore contamination. The new system placed a timber crib two miles offshore, connected by means of Chicago's first water tunnel to the old waterworks at Michigan and Chicago Avenues. This system was the beginning of the modern Chicago waterworks. The Sanitary district of Chicago was formed in 1889. The District reversed the flow of the natural rivers away from the Lake in order to protect Lake Michigan from pollution.[1]

The Beginnings of Federal Involvement

With an ever increasing population, increasing waste discharges began to take their toll. Some believed that wastes would simply decompose; others believed that pollution was the price of progress. A few far-sighted individuals became interested in the problem of pollution but found little or no governmental response.

During the 1930's interest in soil and water conservation swept the country. Stimulated by the passage of federal legislation, soil and water conservation districts were developed at the state level.

It was not until after World War II, however, that an explicit response was made to the problem of water pollution. From that point on, until recently with increased state and local interest, the history of water pollution legislation is a history that takes place primarily at the federal level.

The first Federal Water Pollution Control Act was passed in 1948, but the bill was able to do little more than legitimize the federal role in water pollution abatement. The 1956 Water Pollution Control Act authorized funds for technical and financial assistance so that communities could construct waste treatment plants. There was a 62% rise in sewage treatment plant construction during the first five years of the incentive program compared to the previous five years. The most important provision, however, was that the federal government was empowered to regulate discharges which could lead to interstate pollution. In 1960 President Eisenhower vetoed a bill to increase the grants-in-aid, but with a new administration in 1961, bills were introduced to provide more research, increase grants-in-aid, and extend federal jurisdiction over pollution in all navigable waters. Two opposing camps were formed primarily over the issue of the extension of federal jurisdiction. The National Association of Manufacturers, the Chamber of Commerce and similar groups were opposed to such extension, while conservation groups and other civic organizations supported it. Many state agency representatives opposed broadening and strengthening federal participation in enforcement on the grounds that it could weaken state programs. Municipalities, on the other hand, financially pressed and reluctant to raise sewer rates, were anxious for assistance.

The 1961 version of the Federal Water Pollution Control Act authorized federal action on intrastate streams at the request of the governors of the states. Although sewage treatment was considerably extended, the bills were hampered because Congress was slow in appropriating the money for subsidies it had authorized.

The Act was revised in 1965, requiring states to draw up codes of quality equal to or better than existing conditions for every district waterway. If the standards were not satisfactory to the Secretary of the Interior, the states could have standards imposed on them. Not unexpectedly there was considerable state resistance and because of extensive negotiation few states met the July, 1967 deadline. Only 31 states were in full compliance by January, 1971. It was, however, a time when the federal government acknowledged that water pollution was more than a health problem. The Federal Water Quality Administration was transferred from HEW to the Department of the Interior and was renamed the Federal Water Quality Administration.

In 1970 the President's Council on Environmental Quality, which was created in 1970, reported that since 1965 industrial waste-handling facilities had been developing satisfactorily although the problem of thermal pollution remained. Municipal expenditures, however, were judged quite inadequate.

Secretary of Interior Hickel, impatient with the progress on water pollution, began to take action. He invoked a measure from the 1965 Water Quality Act which allowed federal

COURT INJUNCTIONS AGAINST THOSE NOT COMPLYING WITH THE FEDERAL-STATE STANDARDS. THE MEASURE HAD NOT BEEN USED UP TO THAT TIME BECAUSE THERE WERE SO FEW STATE STANDARDS. HE ALSO USED THE 1899 REFUSE ACT WHICH PROVIDED FOR FINES UP TO $2500 A DAY FOR DISCHARGING WASTE INTO WATERWAYS WITHOUT A PERMIT FROM THE ARMY CORPS OF ENGINEERS; THE PERMIT REQUIREMENT HAD NEVER BEEN IMPLEMENTED.

WHAT WAS NEEDED, HOWEVER, WAS A PIECE OF LEGISLATION THAT COULD ACHIEVE MUCH BROADER RESULTS THAN COULD THE CASE BY CASE PROCEDURE. PRESIDENT NIXON, IN HIS ENVIRONMENTAL MESSAGE TO CONGRESS ON FEBRUARY 10, 1970, PROPOSED A PROGRAM WHICH INCLUDED FEDERAL SEWAGE TREATMENT CONSTRUCTION GRANTS TO BE MATCHED BY STATE AND LOCAL EXPENDITURES, AND THE CREATION OF AN ENVIRONMENTAL FINANCING AUTHORITY TO UNDERWRITE LOCAL FINANCING. MONEY FOR THE GRANTS PROGRAMS WAS APPROPRIATED BUT A PROGRAM SPECIFYING "PRECISE EFFLUENT REQUIREMENTS ON ALL INDUSTRIAL AND MUNICIPAL SOURCES", AND CALLING FOR STRICT ENFORCEMENT, GOT NOWHERE IN CONGRESS, WHICH DECIDED TO TACKLE AIR POLLUTION FIRST. CONSIDERATION OF WATER POLLUTION LEGISLATION BEGAN WHEN THE NEW CONGRESS CONVENED IN 1971 AND ULTIMATELY RESULTED IN THE FEDERAL WATER POLLUTION CONTROL ACT OF 1972. THIS 1972 ACT WILL BE DISCUSSED IN THE NEXT SECTION ON LAWS AND LEGISLATION (SEE ALSO APPENDIX A). FOR THE PURPOSES OF THIS BRIEF SKETCH IT IS SUFFICIENT TO SAY THAT PRESIDENT NIXON VETOED THE BILL BECAUSE THE SENATE HAD REJECTED A BILL GIVING THE PRESIDENT TIGHT CONTROLS ON TOTAL FEDERAL SPENDING. IN THE LAST HOURS BEFORE ADJOURNMENT, CONGRESS OVERRODE NIXON'S VETO OF THE POLLUTION CONTROL ACT.

THE SECOND MAJOR PIECE OF WATER POLLUTION LEGISLATION PASSED DURING THE NIXON ADMINISTRATION WAS THE SAFE DRINKING WATER ACT OF 1974. FROM 1961 TO 1970 THERE HAD BEEN 130 OUTBREAKS OF DISEASE OR POISONING ATTRIBUTED TO DRINKING WATER WHICH RESULTED IN 46,374 ILLNESSES AND 20 DEATHS. BUT THE CONGRESS WAS CONSIDERING NOT ONLY DISEASE, WHICH HAD BEEN THE PRIMARY AREA OF CONCERN IN THE PAST, BUT ALSO THE PRESENCE OF CONTAMINANTS WHOSE EFFECTS WERE LONG-RANGE OR UNKNOWN. THE LEGISLATION WAS TO BE CARRIED OUT PRIMARILY AT THE STATE AND LOCAL LEVEL WITH FEDERAL ASSISTANCE FOR THE SETTING AND REINFORCEING OF STANDARDS. THE ACT CONTAINED, AMONG OTHERS THE FOLLOWING PROVISIONS:

- NATIONAL PRIMARY DRINKING WATER REGULATIONS WOULD BE PRESCRIBED
- REGULATIONS WOULD APPLY TO PUBLIC WATER SYSTEMS AND PRESCRIBE MAXIMUM CONTAMINANT LEVELS
- STATES WHICH ADOPTED AND IMPLEMENTED ADEQUATE STANDARDS AND ENFORCEMENT MEASURES COULD BE GRANTED A VARIANCE FROM NATIONAL STANDARDS
- FEDERAL GRANTS TO ASSIST STATE SURVEILLANCE AND ENFORCEMENT UNDER THE BILL
- ADDITIONAL GRANTS, LOAN GUARANTEES, AND FUNDING OF RESEARCH AND DEMONSTRATIONS
- PROVISIONS FOR THE PROTECTION OF UNDERGROUND SOURCES

ALSO IN 1974 THE HOUSING AND COMMUNITY DEVELOPMENT ACT WAS PASSED, WHICH WAS INTENDED to reorder the relationship between the Federal government and the states. Title I provided for a community development block grant program which consolidated and simplified ten categorical urban development grant programs. Those grants which affected water quality were the Public Facilities Loan Program authorized by Title II of the Housing Amendments of 1955 and the Water-Sewer Neighborhood Facilities and Advanced Land Acquisition Programs (Title VII of the Housing and Urban Development Act of 1965).

With major pieces of water pollution legislation passed under the previous administration, the emphasis of the new Carter administration shifted from issues of quality to issues of conservation and management. As Governor of Georgia, Carter had experienced difficulties with the Army Corps of Engineers. He turned their handling of water projects into a campaign issue and proceeded to base his legislation on it. In his environmental message to Congress on May 23, 1977, President Carter said, "One of the pressing domestic issues facing this Administration and this Congress is the establishment of a national water resources management policy." His attempts to eliminate water projects from public works bills led to considerable opposition in Congress. Six projects chopped from the 1977 legislation were reinstated in the 1978 public works bills. In the waning days of the 95th Congress Carter vetoed the legislation. The veto was sustained by Congress and a last minute push to put together a compromise was defeated.

We have swept broadly across the highlights of the Federal legislation. What can this tell us about the decision-making process? Even the major trends help demonstrate the following two points:

1. that shifts and changes in federal relationships affect the type of legislative response
2. that water quality issues must command sufficient attention from policy makers to be included in the decision-making process.

The Issue-Attention Cycle

Decisions made at the macro-level are conditioned by the currency of an issue in the public consciousness.

Very little attention has been paid to the manner in which issues rise into public consciousness and become translated into policies and programs. And yet we know intuitively that issues which receive a good deal of attention, in the press or other public forums, result in increased interest on the part of the President and legislators, at best to remain responsive to their constituents or at worst to be able to fend off ardent supporters of a cause. Economist Anthony Downs (1972) has characterized this awakening of interest in an issue and its subsequent fading from public consciousness as the "issue-attention cycle". He identifies five stages in the cycle:

1. The pre-problem stage, at which some highly undesirable social ocndition exists but is as yet alarming only to experts or interest groups.

2. Alarmed discovery and euphoric enthusiasm. The public, usually through a dramatic series of events, becomes aware of and concerned about the problem. There is a call for action based on the traditional American assumption that the problem can be solved without any fundamental reordering of society.
3. Realization of the cost of significant progress. The public begins to see that not only a great deal of money, but major sacrifices by the entire population will be required.
4. Gradual decline of public interest. There are varied reactions to the problem of costly solutions--discouragement, suppression and boredom. Usually another problem has reached public consciousness by this time.
5. The post-problem state. New institutions, programs and policies have been created by this point to solve the problem, so that the condition is no longer at the pre-problem stage. The problem may recover public interest on occasion, but public concern is in limbo.[2]

DOWNS SUGGESTED THAT THE CYCLE WOULD PERHAPS MOVE MORE SLOWLY FOR ENVIRONMENTAL ISSUES BECAUSE THEY POSE PROBLEMS THAT AFFECT ALMOST EVERYONE, NOT JUST A MINORITY OF THE POPULATION. IN ADDITION, SUCH PROBLEMS ARE QUITE VISIBLE AND CAN OFTEN BE "PINNED" TO RECOGNIZABLE VILLAINS. COSTS TO INDUSTRIAL POLLUTERS COULD TOO EASILY BE PASSED ON TO CONSUMERS.

IT APPEARS, HOWEVER, FROM OUR HISTORICAL SKETCH THAT THE ISSUE OF WATER QUALITY HAS PASSED THROUGH THE CYCLE DOWNS IDENTIFIED TO THE POST-PROBLEM STAGE. DOWNS' ANALYSIS OF THE CYCLE WAS MORE PERCEPTIVE THAN WAS HIS PREDICTION FOR THE ENVIRONMENTAL MVOEMENT. HE DID NOT FORESEE THE CHANGING ECONOMIC CONDITIONS WHICH ARE THEMSELVES PROBLEMS NOW IN THE ASCENDANCY ON THE "ISSUE-ATTENTION CYCLE". THE "VILLAINS" HAVE BEEN QUITE ADEPT AT SENSITIZING THE PUBLIC TO THE COSTS OF POLLUTION CONTROL IN TERMS OF JOB CUTBACKS AND RISING PRICES, AND HAVE MANAGED TO FIND THEIR OWN VILLAIN: COSTLY REGULATIONS AND POLLUTION CONTROL DEVICES. THERE HAS ALSO SEEMED TO BE SO MANY EXAMPLES OF ENVIRONMENTAL DEGRADATION THAT A SENSE OF FATALISM BEGAN TO DEVELOP: "THERE'S NOTHING WE CAN DO ABOUT IT ANYWAY." THERE IS NO LONGER THE INTENSE PUBLIC INTEREST IN AND SCRUTINY OF THE ISSUES OF WATER QUALITY, AND THIS IS REFLECTED IN THE RESPONSE OF LEGISLATIVE BODIES.

DURING THE YEARS IN WHICH WATER QUALITY ISSUES WERE IN THE ASCENDANCY OF THE ISSUE-ATTENTION CYCLE, FEDERAL AND STATE RELATIONSHIPS WERE CHANGING NOT ONLY OVER ENVIRONMENTAL ISSUES BUT OVER OTHER ISSUES AS WELL. WITH THE INCREASING RECOGNITION OF AN INTERDEPENDENT ECONOMY AND NATIONWIDE PROBLEMS, THERE AROSE A DEMAND FOR NATIONWIDE PROBLEM-SOLVING. THERE AROSE SIMULTANEOUSLY THE PROBLEM OF HOW SOLUTIONS WOULD BE PAID FOR. STATE AND LOCAL UNITS HAVE BECOME INCREASINGLY FINANCIALLY BELEAGURED, AND AS A RESULT HAVE TENDED TO DIRECT THEIR ATTENTION TO SHORT-RUN FINANCING PROBLEMS AND TO FOREGO INTANGIBLE PROGRESS TOWARD A FUTURE GOAL, SUCH AS CLEAN WATER. AS WALTER HELLER, FORMER CHAIRMAN OF THE COUNCIL OF ECONOMIC ADVISERS ONCE WROTE, "PROSPERITY GIVES THE NATIONAL GOVERNMENT THE AFFLUENCE AND THE LOCAL GOVERNMENT THE EFFLUENTS."[3]

Changing federal relationships have been firmly based on financial relationships. The tone of the relationships changed markedly from one of competition to one of cooperation between governmental levels. As Michael D. Reagan (1972) writes:

> ...we have as a nation accepted the notion that it is appropriate for the national community to imbed its scale of values (i.e., those values that a majority of national legislators can agree upon) in programs that offer state and local governments financial inducements to be persuaded that the national scale of values should also be the local priorities.[4]

Grants

Although grants-in-aid are as old as the government itself, their widespread use during the New Deal added a new dimension--substantial federal supervision, even though requirements for matching funds were very high. Matching requirements have been gradually diminishing, but these grants still allow the traditional service deliverers to continue functioning while alleviating their financial burden.

Grants are often a way not only to assist localities in new projects or to provide resources to meet certain standards, but to provide a financial incentive to do something which may have a low priority, such as the provision of better sewage treatment. The power of federal resources to induce change was seen in the remarkable response of municipalities to the assistance provided in the Water Pollution Control Act of 1956.

Federal fiscal relationship during the sixties was primarily based on categorical grants--grants for specific purposes. An example in the water quality area has to do with the programs for sewage treatment facilities:

> Under one program administered by the Farmers' Home Administration, cities of less than 5500 population can apply for grants to finance sewage-collection systems. For cities with a larger population, collection systems are financed by the Department of Housing and Urban Development. In the case of interceptor sewers, which transmit the sewage from the collection systems to the treatment plants, financing is available from the Environmental Protection Agency (EPA). EPA will also finance sewage treatment plants and sewer outfalls under the same grant programs as the interceptors, but these need not be financed under the same grant. The Economic Development Agency also plays a role in financing sewage systems; for economically depressed areas, it will guarantee loans or make grants for any segment of a sewage system from collection to outfall sewer. Normally these grants or loans will finance the local contribution required by EPA, HUD, or FHA grants.[5]

President Nixon, on the other hand, was interested in moving from grants to what was called "special revenue sharing", which would allocate fixed amounts for identified functions. Among the ways in which the program differed was by not requiring matching or maintenance of previous effort. But it proved impossible to return power entirely to state and local hands, particularly on environmental issues. Environmental interest groups have shown themselves more effective at the national level. These groups, which want something done at the state level, but which have greater political clout at the national level, favor the

GRANTS-IN-AID APPROACH. THEY HAVE BEEN ABLE TO MAKE USE OF THE FACT THAT THE FEDERAL LEGISLATURE CAN COMMIT THE NATION TO ACTION WITHOUT BEARING FULL RESPONSIBILITY--AND FULL BLAME--FOR IMPLEMENTATION OF LEGISLATION WHICH, UNDER THESE GRANTS, OCCURS AT LOWER LEVELS OF GOVERNMENT.

REVENUE SHARING DID NOT PROGRESS AS FAR AS THE NIXON ADMINISTRATION WOULD HAVE LIKED. INSTEAD, THE END RESULT OF THE POLITICAL BARGAINING WAS THE INCREASED USE OF BLOCK GRANTS, SUCH AS THE COMMUNITY DEVELOPMENT BLOCK GRANTS.

AFTER THE RECESSION OF THE MID-70'S, THE DISCUSSION OF FISCAL RELATIONSHIPS BEGAN TO TAKE ON A NEW CAST. NATIONAL ECONOMIC ISSUES OF INFLATION, BALANCE-OF-PAYMENT DEFICITS, AND THE DECLINING VALUE OF THE DOLLAR HAVE MADE THE FEDERAL LEVEL SEEM LESS THE CORNUCOPIA IT HAD BEEN CONSIDERED IN THE PUBLIC MIND. BUT, AS WITH OTHER POLITICAL ISSUES, ONCE DISCUSSION IS INITIATED AND CONSIDERATIONS OF NECESSARY CHANGES BEGIN, THE LEGISLATIVE RESPONSE LAGS BEHIND THE INITIAL MOTIVATING FORCE. IT REMAINS TO BE SEEN HOW BUDGETARY CUTBACKS WILL AFFECT PROGRAMS DIRECTED AT WATER POLLUTION PROBLEMS. BUT, ALTHOUGH THE PUBLIC MOOD MAY CALL FOR MORE RESPONSIBLE FISCAL MANAGEMENT, THE DAYS IN WHICH THE FEDERAL GOVERNMENT PLAYED A MINIMAL ROLE IN WATER QUALITY ISSUES IS UNDOUBTEDLY OVER FOR GOOD.

SO FAR WE HAVE BEEN DEALING PRIMARILY WITH LEGISLATIVE RESPONSES TO PUBLIC PROBLEMS. THESE RESPONSES ARE AFFECTED BY DECISIONS MADE BOTH BEFORE AND AFTER THE RESPONSE. DECISIONS ARE MADE IN PLANNING FOR A NEEDED LEGISLATIVE RESPONSE AND, AFTERWARDS, IN DETERMINING THE RULES AND STRUCTURES WHICH WILL GUIDE THE APPROPRIATE AGENCY'S IMPLEMENTATION AND ENFORCEMENT OF THE LEGISLATION. NO MATTER WHO MAKES A DECISION OR IN WHAT SETTING, DECISIONS MAY NOT REPRESENT THE ONE BEST SOLUTION, BUT THE MOST ACCEPTABLE SOLUTION AMONG COMPETING ALTERNATIVES. DECISIONS ARE THE CONSEQUENCES OF "INNUMERABLE AND OFTEN CONFLICTING SMALLER ACTIONS".

VARIOUS ANALYSTS HAVE PROPOSED MODELS OR CONCEPTUAL FRAMEWORKS FOR EXPLORING PATTERNS IN DECISION-MAKING PROCESSES. EACH SUCH CONCEPTUAL MODEL CAN GIVE A DIFFERENT PERSPECTIVE ON A GOVERNMENT ACTION AND THUS INCREASE OUR UNDERSTANDING OF THE END RESULT. WE WILL LOOK BRIEFLY AT THE MODELS PRESENTED BY TWO ANALYSTS AND THEN DISCUSS CONSTRAINTS ON THE DECISION-MAKING PROCESS.

GRAHAM ALLISON (1969) EXPLORED DECISION-MAKING IN FOREIGN AFFAIRS. HIS THREE CONCEPTUAL MODELS ARE RELEVANT FOR ENVIRONMENTAL DECISION-MAKING. ALLISON'S RATIONAL PROCESS MODEL (MODEL I) REGARDS ACTIONS AS THE MORE OR LESS PURPOSIVE ACTS OF UNIFIED NATIONAL GOVERNMENTS. HIS ORGANIZATION PROCESS MODEL (MODEL II) REGARDS DECISIONS AS THE RESULT OF CHOICE AND ACTIONS TAKEN BY LARGE ORGANIZATIONS FUNCTIONING ACCORDING TO REGULAR PATTERNS OF BEHAVIOR. THE EPA'S DECISIONS, FOR EXAMPLE, ARE CONSTRAINED BY ITS LEGISLATIVE MANDATE, White House policy, and the standard operating procedures of the agency. Allison's bureaucratic politics model (Model III) regards decisions as outcomes of overlapping bargaining games among players arranged hierarchically in the national government. A passage from Quarles' Cleaning Up America helps illustrate the positioning that takes place. Quarles (1976), an EPA employee, is defending his agency's regulations on lead in gasoline:

> Earlier confrontations enabled critical issues to surface so that Cabinet officers could appeal directly to the top, or as in this case, so that White House staff could intervene and pursue the argument...It was only because of Dick Fairbanks (a White House staff worker) that were were still receiving flak about our regulations. I thought to myself that if he had been sick, out of town, uninformed, or in agreement we would not have had this trouble.[6]

The kinds of activities represented by all three of Allison's models are no doubt operating at the same time. The manner in which we view the process depends in great part on what we want to see.

Other analysts view decision-making within government by use of a framework derived from systems analysis, an approach to a subject, which assumes that the object of study, even though made up of smaller parts, can be viewed as a discrete entity--a system--which has certain properties and interacts with other systems. Inputs from the environment enter the decision-making process in the shape of demands and proposals. The decision-making system consists of formal and informal power structures which have varying resources at their command. Their decisions are circumscribed by time constraints, information costs, political feasibility, and their direct and indirect relationships with other government structures. The decision-output has some effect on the environment, and feedback on the effects re-enters the system as new input. The systems approach is used to structure complexity. In environmental decision-making we often do not know what the relevant factors-the inputs--should be. In fact, the systems approach becomes unweildly when applied to environmental decision-making because of the bewildering complexity of inputs. Some of the imponderables which affect environmental decision-making are given below.

1) Non-decisions.

A final decision is conditioned by many things which are usually never considered. A certain solution or problem may never be brought up because it is a part of the cultural universe in which an issue arises. No one would realistically propose that people no longer bathe in order to cut down on the amount of dirty water entering the sewer system. Some research suggests that there is little chance for decisions to be made when self-serving elites suppress conflicts that jeopardize their interests, or when a group squelches an issue because it anticipates a negative response from community elites. The issue of non-decisions is of interest in the area of environmental concern because opponents of pollution legislation require a non-decision. A politician cannot afford to be against clean

WATER, FOR EXAMPLE. SO AN OPPONENT OF ANTI-POLLUTION LEGISLATION WILL WANT TO MAKE SURE THE ISSUE IS NOT RAISED AT ALL. ENVIRONMENT PROPONENTS, ON THE OTHER HAND, CAN BE INTIMIDATED BY A POLLUTER'S REPUTATION OF POWER AND, CONSEQUENTLY, DEFER THEIR ACTIVITIES.

2) VALUING THE HARD TO VALUE.

SOME OF THE FACTORS THAT ARE EXPLORED IN POLLUTION DECISIONS ARE DIFFICULT TO EVALUATE.

a. What is health? How does one determine the relation between certain substances in the water and long term health effects? What is a toxic substance?

b. How much restraint are we willing to accept for often very uncertain future benefits? How great is the risk of delay? Will the situation reach the point of no return?

c. How does one value human life or such intangibles as the dignity of a man displaced from a job?

d. What secondary effects result from reducing water pollution? Do these outweigh the costs of reduction? Quantitative methods have been developed to explore these issues. Most people who use such methods will be among the first to point out the value judgments that go into the calculations. Value judgments made on these issues are often made, however, without the benefit of explicit analysis, and yet enter into the decision-making process through political bargaining processes.

3) UNCERTAINTY

RATIONAL DECISIONS ARE MADE BY ASSESSING THE PROBABLE CONSEQUENCES OF VARIOUS ALTERNATIVES. IN ENVIRONMENTAL ISSUES THERE IS EXTREME DIFFICULTY IN MEASURING FUTURE PROBABILITIES. DECISIONS ARE MADE IN AN ATMOSPHERE OF UNCERTAINTY AND THE FACT OF THAT UNCERTAINTY MUST BE TAKEN INTO CONSIDERATION WHEN POLICIES AND PROGRAMS ARE BEING HAMMERED OUT.

4) EXPECTATIONS AND DISINTEREST

IN ENVIRONMENTAL ISSUES THERE IS OFTEN A LAG BETWEEN SUGGESTED ANSWERS OR PROBABLE SOLUTIONS TO A PROBLEM AND THE WILLINGNESS OF THE PUBLIC TO IMPLEMENT THEM. OFTEN IT IS A MATTER OF PUBLIC WILL RATHER THAN PURELY A MATTER OF COST.

ANOTHER PROBLEM WITH THE SYSTEMS APPROACH IS THAT MANY SYSTEMS MUST BE CONSIDERED SIMULTANEOUSLY. AN EXAMPLE OF THE INTEGRATED NATURE OF THE VARIOUS LAKEFRONT ISSUES IS PROVIDED BY A DISCUSSION OF THE CHICAGO LAKEFRONT PLAN (CLP) IN A PREVIOUS PAPER:[7]

> Accompanying the environmental considerations that might be affected by changes in the lakefront expansion are the impacts resulting from any lakefront construction itself. The nature of various construction approaches should be examined to determine the short-term effects of filling operations, bulkhead construction, possible preconstruction dredging, etc. Different types of fill materials will have differing effects on the aquatic species. Here again, engineering factors, in this case construction practices and fill material, could have an influence on the level of impact that a particular design produces, e.g., different island construction techniques could cause varying amounts of fill material to be released to the lake during construction. Depending on the chemical nature of the fill material, the environmental effect on water quality could be significant.
>
> Another important aspect of the environmental assessment problem in the design context concerns the sequential nature of construction. Assessment of the environmental impact will be a necessary task in order to secure the various permits and approvals required to move forward. However, because

of the long-range nature of a lakefront construction program, environmental impact assessment will take on a new dimension. It is estimated that completion of an island-land extension program could take on the order of 10-15 years or longer. During this time period, the series of land extensions, breakwaters and/or islands would probably be constructed sequentially. It is possible that during the interim period the environmental impact of the lakefront system will fluctuate or change. For example, changes in wave refraction patterns caused by the presence of one island may have detrimental effects on the mainland shore system; whereas, the presence of the completed island system may not have the same or any detrimental effects, and might be viewed with respect to its short-range and long-range consequences.

The use of, and access to, the lakefront are important design factors and must be included in the course of both evaluation and impact assessment. The configuration of lakefront activities and its effect on adjacent community zones, on the city itself, and on the metropolitan region, are in the final analysis the measures of ultimate success of the lakefront development. Improved access to the lakefront will need to be achieved, if increased usage is to be encouraged by new development. Some impacts of such increased usage are likely to be felt in the adjacent community zones. The expansion of the lakefront, in turn, may alternatively stimulate or discourage development in the adjacent community zones, depending on the development plans and opportunities of the community, and their compatibility with the particular lakefront design.

As an example, consider the interaction between access, use and design involved in the public safety requirements of an expanded lakefront system. One list of requirements (including cost considerations) such as erosion rates, water quality, traffic, access, etc., may dictate a particular shape, size, and topography of an island. Simultaneously, because of particular user-demand estimates, a specific set of uses is prescribed for that island, e.g., fishing, concerts, boating, aesthetics, etc. At the same time, aesthetic or landscape criteria might dictate a rolling, tree-covered landscape. However, if concert activity or general recreational programs necessitate a need for police patrols, the rolling tree-covered landscape may be in direct conflict with the ability to provide for effective patrolling. The security and safety requirements dictated by the particular design may prove to be too costly or ineffective, and the design consequently may have to be changed.

Similarly, the effect of use and transportation-access factors on the design can be related to the environmental impact issue. As an example, consider the relationship between island shape and size and possible island uses and access. Erosion and water quality constraints may require that an island be placed a minimum distance from the mainland so that littoral drift is not adversely disturbed. However, because of this distance criteria, access to the island may be limited to a level that is not consistent with the objectives of the plan since long bridges may be unattractive, costly, or too difficult to build.

Accordingly, it is evident that the various interactions between environmental impact, design, and use must be carefully considered in defining and carrying out the research programs. In turn, the research programs must provide the basis for testing proposed designs in terms of environmental impact, and to assess the degree to which the plan objectives have been met.

In summary, it seems clear that design, research, and environmental impact do not constitute three separate processes, but rather one integrated analytical effort that together constitute the "lakefront system design and assessment process".

THE INTERRELATIONSHIPS OF SYSTEMS ARE PRESENTED GRAPHICALLY IN THE FOLLOWING MATRIX (TABLE 1), WHICH SUMMARIZES POSSIBLE POLLUTION CONTROL OPTIONS IN AREAWIDE 208 PLANNING:

TABLE 1. FRAMEWORK FOR 208 WATER QUALITY MANAGEMENT (Teska, 1976)

	NON-STRUCTURAL OPTIONS:				STRUCTURAL OPTIONS:	OTHER NON-STRUCTURAL OPTIONS:		
Level of Government	Planning & Coordination	Regulations	Incentives & Disincentives	Acquisition of Property Rights	Construction & Maintenance	Judical Process	Information & Education	Voluntary Action
National	Water Quality NEPA Air Quality Coastal Mgt. A-95 Review	W.Q. Stds. PNDES NEPA/EIS A.Q. Stds. Sec. 404 Permits Sec. 10 Permits Land Reclamation	Flood Insurance Grants & Loans Surplus Land Disposition Dredge Spoils Boats & Ships	Estuarine Sanctuaries Nat's Facilities Sites Flood Control Sites Reservoir Sites National Parks	Dredging Flood Control Erosion Control		EPA Research, Publications, Seminars	Com-Ind. Org. Policies Systems Research Dev. Sale
State	State Policy Coordination Water Quality Air Quality Energy Cons. Diversion & Allocation SEPA/EIS Floodwater Mgt. Coastal Mgt. A-95 Review	Structures in Lake Floodplain Permits Land Reclamation Subdiv. Review NPDES SEPA/EIS Erosion & Sedimentation W.Q. Stds. A.Q. Stds. Water Use Zoning Mining & Quarrying Health Regs. Boats & Ships Energy Facility Stds. Treatment Plant Oper. DMP's Crit. Areas Thermal Regs.	Joint Use Taxation Assessment Grants & Loans Surplus Land Disposition Licenses Certificate of Service	State Parks & Cons. Areas Reservoir Sites Land Treatment Sites Ports & Harbors Development Rights Easements	Treatment Facilities Wastewater Systems Stormwater Systems Erosion Control Systems Flood Control Systems	Public Trust in Lake State Constitution Atty'. Gen.	State Univs. Operator Training Institutes	
Regional	Comprehensive Planning Growth Mat. A-95 Review Water Quality Intergov't. Agreements	Model Regs.		None	None			
Local	Comprehensive Growth Mgt. Water Supply Wastewater Stormwater Floodplain Environmental Quality Air Quality Lakefront Open Space	Zoning Ord. Floodplain Regs. Env. Perform. Subdivision PUD Regs. Buffer Zones Construction Permits Development Permits Housing Code Building Code Hillside Regs. Drainage Regs. Grading Regs. Land Dedication	Density Bonuses Transfer Dev. Rights Taxation Assessment Public Investment User Fees Intergov't. Agreements Mondatory Sewer Hookup Thermal Regs. Erosion & Sediment Regs. Solid Waste Ord. Septic Tank Ord. Agric. & Garden Chem. Ord. Non-conforming Uses	Conservation & Scenic Easements Parks & Open Spaces Floodplains Reservoir Sites Land Treatment Sites Treatment Plant Sites Waste Disposal Sites Ports & Harbors Development Rights Easements Critical Areas	Treatment Facilities Wastewater Systems Stormwater Systems Erosion Control Systems Flood Control Systems	Citizen Law Suits Public Law Suits		Water Use Reduction Commercial Industrial Conversion

Again, agency complexity can be seen in Table 2 of common research concerns at the Federal level:

	Agencies							
		Commerce		Defense	The Interior			
Research Areas	EPA	Sea Grant Program	Lake Survey Center	Corps	BSF&W	Geological Survey	Office of Water Resources Research	AEC
Pollution effects on Aquatic life	X	X		X	X		X	
Water Characteristics	X		X			X		
Movement of pollutants	X	X		X		X	X	X
Mathematical modeling	X	X	X			X	X	
Remote Sensing	X					X		
Pesticides and other toxic substances	X	X			X			
Thermal Pollution	X	X			X			X
Alternative waste treatment methods	X	X		X				

[a] Does not include agency efforts under the IFYGL program, which includes research in all but the last area.

Table 2. Research Areas of General Concern Among Federal Agencies in the Great Lakes[a] (Comptroller General, 1974)

All of these ways of looking at the decision-making process make it quite clear that decisions come about as the result of accommodating divergent interests. This process extends not only to the bargaining that takes place in getting regulations passed, but to the bargaining that takes place to get regulations adhered to.

Matthew Holden wrote a very interesting essay in 1966 on this process. Regulatory decision makers cannot "ordain" results without losing potential for success to the recalcitrance of the regulated. "Successful regulation", he writes, "depends on the consent of the regulated."[8] That consent is achieved through bargaining. For the regulatory agency, the incentive to bargain is the reasonable accomplishment of its mission, failure in which has adverse consequences for the agency and those associated with it.

THE ABILITY TO BARGAIN IS ENHANCED BY AWARENESS OF THE CONSTITUENCIES IN THE DECISION-MAKING PROCESS. ANOTHER EXAMPLE COMES FROM A STUDY ON FACTORS AFFECTING POLLUTION REFERENDA. THE STUDY CONCLUDES THAT ONCE OPPOSITION TO REFERENDA BEGINS THEY WILL NOT PASS; THE OPPOSITION CANNOT BE OVERCOME. IT IS INCUMBENT ON THE COMMUNITY TO FIND THE RELEVANT CONSTITUENCIES AND GAIN THEIR ACCEPTANCE IN ADVANCE. A PARTIAL LISTING OF THESE GROUPS IS GIVEN IN TABLE 3.

GROUPS TO BE CONSULTED

GROUP	INTEREST	LIKELY POSITION ON BOND	RESOURCES
CHAMBER OF COMMERCE	LAND DEVELOPMENT, ECONOMIC DEVELOPMENT, EMPLOYMENT, LOW TAX RATE	FOR	MONEY PRESTIGE
TAXPAYERS ORGANIZATION	LOW TAX RATE, LOW ASSESSMENT	AGAINST	NUMBERS OF MEMBERS
GOOD GOVERNMENT ORGANIZATION (LEAGUE OF WOMEN VOTERS)	ENDING WATER POLLUTION INFORMED ELECTORATE HONEST GOVERNMENT	FOR	PRESTIGE RESEARCH
LOCAL AND REGIONAL PLANNING AGENCIES	ENDING WATER POLLUTION EFFICIENTLY CONSISTENCY WITH EXISTING PLANS	FOR	RESEARCH AUTHORITY TO WITHHOLD FUNDS
HOMEOWNERS	PRESERVATION OF CHARACTER OF COMMUNITY LOW TAX RATE	AGAINST	NUMBER OF MEMBERS COHESIVENESS
MINORITY GROUPS	EQUITABLE DISTRIBUTION OF COSTS AND BENEFITS OF PROJECT IMPROVED PUBLIC SERVICES	UNKNOWN	NUMBER OF MEMBERS COHESIVENESS

TABLE 3. CONSTITUENCIES IN THE DECISION-MAKING PROCESS (A6T ASSOCIATES INC., 1971).

PLANNERS, ADMINISTRATORS AND IMPLEMENTERS HAVE MORE OPPORTUNITY TO CONSIDER PROBLEMS AND POSSIBLE SOLUTIONS IN GREATER DETAIL. AT THIS LEVEL MANY MODELS HAVE BEEN DEVELOPED

WHICH ATTEMPT TO EXPLAIN DECISIONS AS WELL AS OFFER METHODS FOR THE CLARIFICATION OF FUTURE CHOICES. A CLEAR EXPLANATION OF THE THREE PRIMARY DECISION-MAKING METHODOLOGIES IS GIVEN IN A REPORT BY THE NATIONAL RESEARCH COUNCIL COMMITTEE ON ENVIRONMENTAL DECISION MAKING.[9]

A. COST-BENEFIT ANALYSIS

Cost benefit analysis is a procedure for comparing the costs and benefits of alternative policies. This procedure relies on specialized techniques and principles, most of which are derived from economic theory. Its purpose is to aid in the fundamental task of allocating the economy's scarce resources among alternative uses so as to enhance allocative efficiency. But allocative efficiency is only one of the considerations that policymakers take into account in evaluating proposals. For example, considerations of equity and political acceptability are also relevant and sometimes decisive.

For purposes of a cost-benefit comparison, the benefits of a proposal are defined to be the amount that people would be willing to pay for the proposal's results. For example, conceptually the benefits from air pollution abatement would include the amounts people would be willing to pay for all the effects associated with cleaner air. These effects might range from lower cleaning costs and lessened plant damage to improved human health and more frequent sunny days. Some of these benefits are amenable to straight-forward quantification and monetization, while others pose both conceptual and practical difficulties. These difficulties can render comprehensive benefit analysis a complex undertaking.

It is generally agreed that a useful concept of costs in a cost-benefit framework is that of opportunity costs. Opportunity most refers to the value foregone in employing a resource in one activity rather than in its best alternative use. For example, when a water pollution control program is undertaken, resources (such as labor and materials needed to construct a sewage disposal plant) must be diverted from other uses. The value of the foregone production and consumption that results from this diversion of resources represents the opportunity cost of the control program. In addition, there may be undesired environmental, economic, or social effects that are not fully captured as part of the opportunity cost of the control program. A complete cost analysis should attempt to define these effects clearly and take them into account.

B. COST-EFFECTIVENESS ANALYSIS

For some environmental decisions, the objective may be taken as given. In such cases the policymaker can use cost-effectiveness analysis to determine the least-cost ways of achieving the set of objectives. The basic difference between cost-effectiveness analysis and cost-benefit analysis is that cost-effectiveness analysis takes as given the level of beneficial outputs (objectives) whereas cost-benefit analysis can be used to examine a range of beneficial results in order to ascertain the level at which net benefits (benefits minus costs) is greatest. For example, cost-benefit analysis might be used to look at the costs and benefits of various pollution standards in order to find the "optimal" economic standard for emissions from mobile sources. A cost-effectiveness analysis, on the other hand, might be used to look at the least-cost methods of achieving pre-specified emission standards.

Thus, as defined here, cost-benefit analysis and cost-effectiveness analysis are not two different approaches to the same problem. Rather each is a procedure that can be applied to a distinct set of problems. Furthermore, it might be argued that cost-benefit analysis can be used to address higher-order questions than cost-effectiveness analysis. Where cost-effectiveness analysis can be used to ask: what is the least-cost means of attaining a desired emissions standard (assuming "costs" can be unambiguously compared); cost-benefit analysis can be used to ask: what is the most economically efficient standard in the first place?

C. DECISION ANALYSIS

Environmental decisions are made under conditions of uncertainty. This uncertainty may be concerned with the abundance and distribution of chemicals in the environment; the rate of diffusion of such substances in the atmosphere, water or soil: the impact of changes in environmental quality upon human health and other organisms; the values that should be attached to possible outcomes of a decision, e.g., how to value certain health benefits or the cost assessments of yet unproven technologies; and the effectiveness of implementing a particular decision. These and other uncertainties are inherent in the problem of deciding what uncertainties are inherent in the problem of deciding what environmental policies to choose. Decision analysis is a technique designed to make these uncertainties explicit thereby subjecting them to discussion, debate, and modification.

Decision analysis does not supplant or make unnecessary other methods of analysis such as cost-benefit analysis or cost-effectiveness analysis. Rather, decision analysis should be looked upon as a technique for incorporating uncertainty into these other forms of analysis.

The application of decision analysis to a problem follows a well-defined sequence of steps. The first step is called the "deterministic phase." In this phase, the decision to be made is defined, i.e., the analyst poses the question: what is to be decided? Possible alternative actions are identified. The possible outcomes for each alternative action are analyzed. These outcomes are often difficult to describe, since this part of the analysis may include many elements--for example, health effects, climatic impacts, reproduction cycles of insects--that are not, in fact, completely known. Nevertheless, in this phase of the analysis, such variables are treated as if they were known accurately so that calculations can be performed to indicate how outcomes are affected by a particular decision. The values placed upon the chain of events leading from decision to outcome are assigned by the analyst. This part of the analysis is similar to a properly done cost-benefit analysis. The same problems occur in both, e.g., how to compare the value of inherently incomparable considerations such as cost of pollution abatement and public health. The deterministic model can be used to perform a sensitivity analysis to examine how the values attached to certain outcomes vary with changes in poorly known variables. In this part of the analysis, the impact of uncertainty is evaluated quantitatively. Sensitivity analysis can pinpoint those variables for which better information would be important and can also identify variables that are unimportant to the decision despite the fact that they are inexact.

The second phase of decision analysis is called the "probabilistic phase." During this phase of the analysis data are gathered on all important variables and encoded in the form of probability distributions (Howard, 1966). This is probably the most controversial part of decision analysis, since the translation of poorly understood data, scarce information, and scientific opinions into probability distributions often depends on considerable subjective judgment. The advantage of decision analysis is that it forces these judgments to be made openly and subjects them to discussion. On the other hand, decision analysis is often sufficiently complex to require computer calculations and there are many who fear that this can mask the fact that subjective judgments entered in the formulation of the problem and in the assignment of important probability distributions. It should be kept in mind, however, that it is better to have a method that deals explicitly with uncertainty than to hide uncertainty in computations that carry an air of certainty unwarranted by the data.

Methods to encode knowledge, even vague knowledge, into probability distributions for use in decision analysis are treated in several references. The third phase of decision analysis is known as the "informational phase". After the problem has been formulated, the sensitivities determined, and the knowledge encoded as probability distributions, an analysis is made comparing the expected cost of obtaining more information (on matters having broad probability distributions, i.e., those that are particularly uncertain) with the expected value of the additional information. The analysis can show whether it is worth purchasing more information or whether the decision should be made with the data at hand.

Ultimate decisions are a reflection of the interplay between political decision-making and technical considerations. One difficulty is that there is usually a gap between our technical knowledge and our ability to use it and, likewise, our ability to implement plans that have been made.

The materials attached as Appendix A presents portions of a step-by-step plan for the Lakefront Land Development Alternatives Implementation Phase. Even though the report stresses Chicago and the State of Illinois, the procedures it outlines have applicability throughout the Lake Michigan area and, in fact, other areas as well. Despite the Report's methodological clarity, there is not one functional step which might not have some stumbling blocks. Missing is mention of the political setting, the relevant constituencies, and potential points of opposition. These things may not need to be explicitly stated, but implementation is a pipe dream unless the planner has considered these aspects as well.

Before moving to agency activities in the area of water quality, we should briefly mention two aspects of decision-making which, while implied in the previous sections, were not explicitly stated.

1) Decisions move slowly, based on previous decisions--the process of incrementalism. Decision rules based on previous experience reduce the information load of the decision maker.
2) This does not mean, however, that innovation cannot and does not take place. Jack Walker (Davis, 1970) studied patterns of innovations among the states. He found that the wealthier, more industrialized states took the lead in policy innovation that was followed by the other states through emulation aid diffusion.

Public Agency Involvement in Lake Michigan Water Quality

The environs of Lake Michigan contain the diversity of habitats found nowhere else in our country except along the oceans. None of the state capitols are near the Lake shore. For most of the legislators in Indianapolis, Lansing, Madison and Springield, the Lake is an issue of secondary concern to their constituents, and an indirect concern for legislators.

Direct concern is found in the agencies that must administer and enforce the laws and regulations which have been sifted through the political decision-making process.

There is a potential in the Lake Michigan area for innovative approaches to water quality. The Lake offers a unifying theme for interstate cooperation on issues of regional development. States often prove to be the testing ground for innovations that become national in scope. Patterns of regional cooperation could become the wave of the future if worked out successfully around Lake Michigan.

Appendix B includes a list of Federal, Interstate, State and Local agencies involved with Lake Michigan water resources. A "Q" denotes agencies who have major responsibilities for water quality recognizing that the use of any water resource impinges in some way on water quality. Appendix C provides more information for those interested in the Environmental Protection Agency.

The State of Indiana recently compiled a summary of all agencies affecting water quality in their state. Rather than duplicating their effort, we have expanded it to include the other States which surround the Lake. We would like to thank the State of Indiana for their kind permission to let us edit and extend these materials for this chapter.

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[1] Illinois Technical Advisory Committee on Water Resources, Water for Illinois, A Plan for Action. Springfield, Illinois. March, 1967, pp. 117-119, 172-174; also Douglas Schroeder, The Issue of the Lakefront, Chicago Heritage Committee, pp. 1-4.

[2] Anthony Downs, "Up and Down with Ecology--The Issue Attention Cycle," Public Interest. 28 (1972) : 38-50.

[3] Walter W. Heller, New Dimensions of Political Economy, Harvard University Press, Cambridge, Mass., 1967, p. 129.

[4] Michael D. Reagan, The New Federalism, Oxford University Press, New York, 1972, p. 81.

[5] Reagan, pp. 60-61.

[6] John Quarles, Cleaning Up America: An Insider's View of the E.P.A., Houghton Mifflin, Boston, 1976, p. 130.

[7] John Armstrong, Robert Gemmell, Jack Meltzer, and Mark Reshkin, Chicago Lakefront Development: A Proposed Research Agenda, October 31, 1975, pp. 23-28.

[8] Matthew Holden, "Pollution Control as a Bargaining Process: An Essay on Regulatory decision-Making," Cornell University Water Resources Center, Publication No. 9, Ithaca, New York, October 1966, p. 11.

[9] Commission on Natural Resources, Decision-Making in the Environmental Protection Agency, National Research Council. Washington, D.C., 1977, pp. 219-223.

[10] Jack L. Walker, "The Diffusion of Innovation Among the American States," American Political Science Review 63 (1969) : 880-889.

APPENDIX A

Source: Verbatim extract from: Khoerle, Bender, Stone and Associates, Inc. for the City of Chicago, Lakefront Land Development Alternatives Report, 1973.

FUNCTIONAL STEPS FOR PROGRAM IMPLEMENTATION

1. Planning Studies, Reviews and Recommendations by the Chicago Department of Development and Planning.
2. Decision to Implement Program by Mayor.
3. Assignment of Program to Chicago Department of Public Works for Implementation.
4. Establish organization for Program Administration, Staff and Fund.

   Some functional responsibilities are:
   - (a) Research and Data Collection for Project.
     - 1) Evaluation of past and current research.
     - 2) Initiate and control new research and data collection.
     - 3) Liaison and coordinate with other agency data collection and instrumentation.
   - (b) Engineering
     - 1) Studies, criteria, stage sequencing, surveys, investigations, etc.
     - 2) Design and Specifications, utility arrangements, etc.
     - 3) Contract Administration, technical inspection, materials control, etc.
   - (c) Interagency Liaison and Coordination
     - 1) Interagency Agreements.
     - 2) Implementation of Policy Guidance.
     - 3) Maintain Channels of direction and information.
     - 4) Planning and Regulatory agency liaison.
     - 5) Liaison with all affected public agencies.
   - (d) Financing and Cash Flow.
     - 1) Grant Applications.
     - 2) Requests for Appropriations.
     - 3) Cash Flow and Bookkeeping.
     - 4) Participating Agency Accounting.
   - (e) Information and Public Contact.
     - 1) Public information and media.
     - 2) Complaints and requests.
     - 3) Public Hearings assistance.
     - 4) Citizen Group Contact.
   - (f) Legal Liaison.
     - 1) Determine needed and desirable legislation for all levels of Government.
     - 2) Assist and provide information for preparation of Legislation.
     - 3) Determine needs and assist in necessary acquisitions.
     - 4) Provide information and assistance related to legal matters.
     - 5) Legal aspects of interagency agreements.
5. Prepare Engineering Report for first stages of the project.

Prepare Environmental Impact Statement for first stages of the project.

The preparation of these documents require close coordination with participatory, policy, and regulatory agencies and should utilize input from agencies which can provide advisory services.

The purpose of these documents is to provide a framework for design and to reduce the number of hearings and the time required for reviews of individual elements of the project.

Because of the need to coordinate with early construction schedules of portions of the Tunnel and Reservoir project, it will not be practical to delay initial critical element design until these documents are available. A certain risk that early designs may not be optimum in terms of the total project should be off-set by the sure value of being able to use the available spoil for landfill.

Determine Financing and Scheduling.

Tentative scheduling and financing developed in the Engineering Report should be refined as detailed interagency agreements are developed.

6. Investigate Possible Participatory Agencies and Possible Funding Agencies and negotiate interagency agreements among the primary Agencies involved.
7. Establish Policy Guidance and Control Organization and Arrangements.
8. Formulate Design Criteria, standard specifications and set up procedures for initial contract administration and cash flow.
9. Prepare Preliminary designs for critical elements of final stage construction. This work includes field control surveys, lake bottom mapping and necessary subsurface investigations. This step is critical with respect to timing as field work is constrained by weather and season.
10. Acquire needed riparian rights for the critical portions of the project. This work should begin as early in the project as possible and if pursued diligently may not be a critical consideration in scheduling.
11. Submit preliminary plans for first stage critical portions of the project and overall early stage Engineering Report and Environmental Studies and Impact Statements to regulatory agencies for review. Assist in publicity and public hearings. Obtain all necessary permits and approvals.

    If both preliminary detail plans for critical portions of the project and reports for total early project stages can be coordinated so that reviews and hearings for both can be made at the same time, it should be possible to reduce the time required for reviews.

    Normal reviews for public works projects vary in time from a few months to sometimes a year or two. It will be necessary to obtain commitments from reviewing agencies to set up special review channels and to assign priority to this project in order to shorten the time required for this step of the program.

    (a) Regulatory Agency approvals.
        1) All Federal approval requests are submitted to the U.S. Army Corps of Engineers who deal with the appropriate Federal Agencies and who will schedule and hold necessary public hearings.
        2) All State of Illinois approval requests are submitted to the Department of Transportation who deal with the appropriate State Agencies.
        3) Approval requests to Independent Bodies are handled individually.
        4) Approval requests to City of Chicago Agencies would be handled by normal channels through the Department of Public Works.
    (b) Policy Approvals should be channeled through a policy guidance control organization set up for that purpose.
    (c) Participatory Agency approvals should be handled through normal coordination channels.
12. Begin field work and preliminary design work for second stage portions of the project. Prepare environmental statements.

    This work should be scheduled to permit field work to be done without winter interruption.
13. Complete final design of critical contracts. Detail design work normally would continue during the period of regulatory agency review. A certain period of time after permits are received is necessary to put plans and contract documents in final form.

14. Approve, advertise, and let critical contracts. This operation is standardized by each public agency. It is prudent to allow about 90 days for these contractural operations.

    Contracts should be let as early in the year as possible to obtain better competitive bidding and to take full advantage of the construction season.

15. Begin construction of critical contracts.
16. Reviews and issuance of permits for the second stage design contracts. Public hearings may or may not be required.
17. Complete design of second stage contracts.
18. Approve, advertise and let second stage contracts for spring construction.
19. Repeat appropriate steps for future portions of the project.

Any of the major participating agencies could design and let construction contracts for any portions of the project which might be best built as part of another contract so that construction coordination and control could be simplified. Design criteria, specifications and schedule control for total project management would be supplied by the prime agency in conformance with policy guidance and the detailed interagency agreements.

Appropriate allocation of funds would be needed for each major segment of the project.

APPENDIX B

"FEDERAL AGENCIES"

SOURCE: STATE OF INDIANA

U.S. DEPARTMENT OF AGRICULTURE

OVERALL WATER OBJECTIVE:	To help landowners protect the soil, water, forests and other natural resources.
AGENCIES	
Farmer's Home Administration	
Provides	-loans to public entities to develop community facilities for public use in rural areas and towns of up to 10,000 people. -funds to construct, enlarge, extend or improve water and sewer systems -grants for up to 50% of the project development costs for water and waste disposal systems. -Resource Conservation and Development loans after project plan accepted by the Secretary of Agriculture -Watershed loans to protect and develop land and water resources in small watersheds -loans to farm owner-operators for purposes which include drilling wells and improving water supply systems for home use, livestock, and irrigation

Agricultural Stabilization and Conservation Service

Agricultural Conservation Program

Provides	-cost-sharing of up to 90% with farmers to carry out needed conservation and environmental practices.

Forest Incentive Program

Provides	-cost-sharing of up to 75% with farmers and woodland owners to plant trees for forest products and improve existing woodlands.

Forest Service

Promotes	-multiple-use management of the Nation's forest resources
Identifies	-opportunities for enhancing stream flow characteristic, controlling flood and erosion, and improving water quality
Manages	-the National Forests and the National Grasslands

The Soil Conservation Service

Cooperates	-with other Federal, State, and local agencies in studying the watersheds of rivers and other waterways -with local sponsors, State and other public agencies in the planning and installation of works of improvement to reduce erosion, floodwater, and sediment damage, and prevent floods including the development of recreational facilities and the improvement of fish and wildlife habitat
Provides	-loans to local organizations to help finance the local share of the cost of carrying out planned watershed and flood protection works of improvement -technical assistance, through conservation districts, to landowners and operators in carrying out locally-adopted soil and water conservation programs.
Assists	-local sponsors to develop and carry out multi-county resource conservation and development projects
Conducts	-investigations and surveys of proposed small watershed projects in response to requests made by sponsoring local organizations, and assisting sponsors in the development of watershed plans.

The Service has primary responsibility for the national cooperative soil survey.

U.S. DEPARTMENT OF DEFENSE

AGENCIES

United States Army Corps of Engineers

Civil Works Program	-the Nation's major Federal water resources development activity -involves engineering works to provide flood protection for cities and major river valleys reduce the cost of transportation supply water for municipal and industrial use generate hydro-electric power provide recreational opportunities regulate the rivers for many purposes including the improvement of water quality and the enhancement of fish and wildlife protect the shores of the oceans and lakes
Protects	-navigable waters of the U.S.
Provides	-planning assistance to States and other non-Federal entities for the comprehensive management of water resources, including pollution abatement works

U.S. DEPARTMENT OF COMMERCE

AGENCIES

The Maritime Administration

Administers	-programs to aid in the development, promotion, and operation of the U.S. Merchant Marine
Conducts	-programs to develop ports, facilities, and internodal transportation, and to promote domestic shipping, including that related to the Great Lakes

The National Oceanic and Atmospheric Administration

Provides	-weather and river observations and forecasts to the general public -special services in support of aviation, marine activities, agriculture, forestry, urban air quality control, and other weather-sensitive activities
Issues	-warnings against such destructive natural events as hurricanes, tornadoes, floods
Monitors	-and reports all non-Federal weather modification activities conducted in the U.S.

Both agencies share a memorandum or understanding regarding the Coastal Zoning planning effort which effects port development and commercial navigation in the Great Lakes.

U.S. ENVIRONMENTAL PROTECTION AGENCY

OBJECTIVE		To permit coordinated and effective governmental action on behalf of the environment
	Develops	-national programs, technical policies and regulations for water pollution control and water supply -water quality standards and effluent guidelines -programs of technical assistance and technology transfer
	Provides	-technical direction, support and evaluation of regional water activities -training in the field of water quality
	Administers	-grants for water quality management

Programs carried out through or by State agencies:

1) Section 201 of the Clean Water Act of 1977 (P.L. 95-217) authorizes Federal Grants for up to 75 percent of the cost of planning, designing and building municipal sewage treatment facilities.
2) Section 208 of the Act authorizes USEPA to make financial assistance available to State and local planning agencies for areawide waste treatment management planning.
3) Section 108 of the Act authorizes projects to demonstrate new methods and techniques for the elimination or control of pollution within the watersheds of the Great Lakes.
4) Section 314(b) of the Act provides for the restoration of publicly owned fresh water lakes.
5) The National Pollutant Discharge Elimination System (NPEDS) program sets strict deadlines for cleaning up the Nation's waterways. Municipal sewage treatment plants and industries discharging into navigable waters must install needed pollution control equipment and must obtain permits which limit the kinds and quantities of pollutants that can be discharged.
6) The Safe Drinking Act of 1974 (P.L. 93-523) authorizes a program for the protection of drinking water by establishing national health standards for microbiological, turbidity, chemical and radiochemical contaminants.
7. The Act also provides for the protection of underground sources of drinking water through the Underground Injection Control Program, the Surface Impoundments Assessment and the

Sole Source Aquifer programs.

3) The Resource Conservation and Recovery Act of 1976 (P.L. 94-580) provides additional safeguards for groundwater as part of the categorization and regulation of open dumps and sanitary landfills.

U.S. DEPARTMENT OF HOUSING AND URBAN RENEWAL

The Section 701 Planning Assistance Program

Promotes -comprehensive planning activities

Provides -grants to States for statewide planning and assistance to cities and other municipalities with less than 50,000 population, counties and metropolitan areawide planning organizations

The Federal Disaster Assistance Program

Manages -programs dealing with disaster research, preparedness, readiness evaluation, disaster relief and recovery

Coordinates -other agency disaster assistance activities

The Federal Flood Insurance Program

Provides -federally subsidized flood insurance at affordable rates to property owners in eligible communities

Community Development Block Grant Program

Provides -grants to communities for a variety of physical development and social service activities, including funding water and sewer lines, water treatment facilities, wells, street and parking lot paving, park development, etc.

U.S. DEPARTMENT OF INTERIOR

AGENCIES

Office of Water Research and Technology

Disperses -allotments for the operation of Water Resources Research Centers in each of the 50 states

Supervices -research grant program which provides money for a wide variety of research activities relating to water resources, including ecological and environmental relationships to water, basin modeling, planning, hydrology, demands on the water table from multiple wells, water purification and recycling.

Fish and Wildlife Service

Monitors -the effects of pollution on fish and wildlife populations

Assesses -the environmental impacts of various water related projects through river basin studies

Promotes -the preservation of environmentally significant streams and wilderness areas

-the improvement and maintenance of fish and wildlife resources through proper management

Provides -reimbursement to States for up to 75% of the cost of approved fish and wildlife restoration and management programs and projects

Operates -wildlife refuges and fish hatcheries

National Park Service

Administers -an extensive system of national parks, monuments, historic sites, recreation areas and the national wild and scenic rivers program

Sponsers -various studies and monitoring programs which assess the water resource situation with respect to their properties

Geological Survey

Cooperates	-with other Federal, State, and local agencies to collect data on the quantity, quality, and use of the Nation's water resources
Conducts	-analytical and interpretive water resource appraisals describing the occurrence, availability, and the physical, chemical, and biological characteristics of surface and ground water
	-research in hydraulics, hydrology, and related fields in order to understand hydrologic systems sufficiently well to quantitatively predict their response to stress, either natural or manmade
Disseminates	-the water data through reports, maps, computerized information services, and other forms of public releases
Coordinates	-the activities of Federal agencies in the acquisition of water data for streams, lakes, reservoirs, estuaries, and ground waters
Provides	-scientific and technical assistance in hydrologic fields to other Federal, State and local agencies, to licensees of the Federal Power Commission, and to international agencies on behalf of the Department of State

Heritage Conservation and Recreation Service

Identifies	-classifies, and registers natural, cultural and recreational resources
Formulates	-policies and programs relative to insuring the preservation of these resources
Coordinates	-Federal, State and local heritage resource and recreation policies and actions
Assists	-an implementation of national and State heritage and recreation projects and programs through Federal, State and local agencies, private organizations and individuals

U.S. DEPARTMENT OF TRANSPORTATION

Decisions made by DOT in conjunction with the appropriate State and local officials strongly affect other programs such as land planning, energy conservation, scarce resource utilization, and technological change.

The U.S. Coast Guard	Serves in DOT except when operating as part of the Navy in time of war or Presidential direction
Enforces	-rules and regulations governing the security of ports and the anchorage and movement of vessels in U.S. waters
	-or assists in the enforcement of all applicable federal laws on the navigable waters of the U.S.
Prevents	-detects, and controls pollution on navigable water of the U.S.
Administers	-a boating safety program aimed at making operation of small craft on U.S. waters both pleasurable and safe
	-and enforces Commercial Vessel Safety Regulations
Establishes	-and maintains aids to navigations and administers the regulatory program for bridges
Provides	-flood relief and removes hazards to navigation

U.S. DEPARTMENT OF ENERGY

Administers	-the licensing of hydroelectric facilities, reviews plans for dams proposed by Federal agencies and makes recommendations concerning facilities

for the development of hydroelectric power

Conducts -activities relating to research and development of various sources of energy

INTERSTATE COMMERCE COMMISSION

Regulates -interstate surface transportation which includes transportation on inland waterways. The Commission's regulations encompass not only the economic aspects of the various modes of interstate transportation, but also the transportation service area in which the Commission grants the right to operate.

NUCLEAR REGULATORY COMMISSION

Licenses -and regulates the uses of nuclear energy by licensing persons and companies to build and operate nuclear reactors and to own and use nuclear materials. It sets standards and makes rules for these types of licenses.

Inspects -the activities of licensees

DEPARTMENT OF PUBLIC HEALTH

Office of Consumer Health Protection

Division of General Sanitation

- administers and enforces state laws and regulations pertaining to facility sanitation, sanitation codes and consumer health services
- enforces specific statutes and rules and regulations pertaining to water supplies, sewage disposal, and other safety and sanitation requirements

Division of Swimming Pools and Recreation

- administers the statewide swimming pool, recreational area, and youth camp programs to insure safe and sanitary swimming

DEPARTMENT OF TRANSPORTATION

Division of Water Resources

- prepares plans and specifications and supervises construction of water resource development projects throughout the State which have been specifically authorized by the General Assembly, e.g., earthen dams, levees, sea wall, pumping stations for flood control, etc.
- regulates public waters and construction in flood plains
- allocates water diverted from the Lake Michigan watershed
- operates and maintains the McHenry Lock and Dam on the Fox River

ILLINOIS E.P.A.

- proposes, advises on, or responds to formal inquiries for standards
- researches and recommends action on variance requests from established standards
- conducts surveillance activities adequate to detect violations of the law, standards or regulations and provides evidence adequate for successful prosecution
- issues permits for construction and operation of facilities
- certifies facilities as adequate to meet standards for tax adjustment purposes
- administers state anti-pollution bond act construction grants program
- approves and certifies applications for Federal construction grants
- prepares environmental quality management plans

-proposes, adopts and implements plans for action in the event of air pollution episodes

-trains and certifies operators of public water supply and sewage treatment facilities

-trains operators of solid waste disposal facilities

-disseminates information

POLLUTION CONTROL BOARD*

-considers enforcement cases, variance petitions, and permit appeals

-issues orders and sets penalties after open, public hearings governed by:

rules of evidence
sworn testimony
right of cross examination
recorded proceedings
written decisions

-adopts environmental quality standards after open public hearings governed by:

rules of evidence
sworn testimony
right of cross-examination
recorded proceedings
written decisions

*Though its members are appointed by the Governor on a schedule of staggered terms, the Pollution Control Board is created by law as a fully independent agency.

INSTITUTE FOR NATURAL RESOURCES

-cooperates in the development of interdisciplinary approaches to the solution of environmental and energy problems

-conducts research and provides assistance

-obtains, stores and processes environmental data

-recommends long range goals and technological, administrative and legislative changes

-proposes rules and regulations

-provides expert testimony

-cooperates with other Federal, State, and local government research agencies

-sponsors annual conference

State Geological Survey**

-studies the rock and mineral resources of the State, mapping its surface and determining the composition of its geologic deposits

-interprets this information for citizens of the State to apply to the varied needs of our cities, industries, governmental units and land owners

-furnishes data essential for construction of dams, reservoirs, and highways, for location of ground-water supplies and mineral deposits, and for development of topographic maps of the State

-aids in the location of special industrial facilities, drainage systems, and waste disposal by deep wells, sanitary landfills or other surface facilities

State Water Survey

-studies the many aspects of the nature and extent of Illinois water resources, providing basic, needed information for the development and conservation of water

-gathers facts, conducts investigations and research to assess and evaluate the quantity and quality of the surface and underground water resources of the State

-makes related studies of water use and conservation, development of water supplies, water resources planning and management and the meteorologic factors that affect water resources

-cooperates with the State and Federal agencies concerned with water and the environment and makes special studies to meet the research needs of planning and environmental agencies.

**The State Geological Survey and the State Water Survey became divisions of the Institute for Natural Resources on January 1, 1979.

INTERSTATE AGENCIES

SOURCE: STATES OF INDIANA AND WISCONSIN
GREAT LAKES COMMUNICATOR

GREAT LAKES BASIN COMMISSION

This water resources agency was established under the Water Resources Planning Act of 1965. Its members are the eight Great Lakes States together with the Federal agencies which have responsibilities in the area.* This commission serves as the principle agency for the coordination of plans for the development of water and related land resources in the states of the Great Lakes Basin.

GREAT LAKES COMMISSION

The Great Lakes Commission supercedes the Deep Waterways Commission which was established to promote the St. Lawrence Seaway project. The Commission acts on behalf of the eight Great Lakes states listed above and the provinces of Ontario and Quebec, Canada. The commission functions in the areas of environmental quality control, shoreline use and recreation, navigation and commerce, fisheries and wildlife, and freshwater resources, encompassing environmental quality and orderly, efficient regional development as these relate to water quality and water availability. It promotes the planning and development of state and regional programs and activities to the executive departments and agencies of the Federal Government and the U.S. Congress, the member states, and any public or private agency having jurisdiction in the basin.

UPPER GREAT LAKES REGIONAL COMMISSION

Two Lake Michigan states belong to this federal-state-local Commission--Wisconsin and Michigan. The third member state is Minnesota. There is a federal co-chairman and 119 member counties from the three-state region. The Commission su-ports the state involvement in carrying out and evaluating economic programs and projects, primarily through the mechanism of technical assistance grants, and grants to supplement federal grants.

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*Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, Wisconsin, Great Lakes Commission, U.S. Departments of Agriculture, Army, Commerce, Housing and Urban Development, Interior, Justice, State Transportation, and the U.S. Energy Research and Development Administration, the U.S. Environmental Protection Agency, and the Federal Power Commission.

STATE AGENCIES

EDITED FROM: ILLINOIS BLUE BOOK
MICHIGAN MANUAL
WISCONSIN BLUE BOOK
INDIANA PRELIMINARY REPORT TO THE GOVERNOR'S WATER RESOURCE STUDY COMMISSION
ILLINOIS E.P.A. ANNUAL REPORTS

ILLINOIS

DEPARTMENT OF AGRICULTURE

Bureau of Soil and Water Conservation

There are 98 organized districts in Illinois involving all of the agricultural land in the state.

-administers the Illinois Soil and Water Conservation Law. Districts are charged by the State with the responsibility to protect and develop the revewable natural resources within their respective jurisdictions.

-provides information and advice on watershed development projects

-sponsors field investigations and reviews of proposed projects

-files reports and recommendations to the Natural Resources Development Board for their consideration and final recommendation to the Governor and his clearing house.

-evaluates district policies, programs, budgets, financial statements and activities for the purpose of allocating grant-in-aid funds

-disseminates information on current related issues and problems

-provices supplemental land surveys and preliminary investigations on approved watersheds, providing for the employment of engineers in cooperation with the Soil Conservation Service of USDA in the preparation of watershed plans and designs for works of improvement

DEPARTMENT OF CONSERVATION

Fisheries Division

-cooperates with other governmental agencies in water resource development and research

-engages in fisheries management activities including: fish population analysis, creel census, aquatic vegetation control, rehabilitation of fish populations, fish stocking recommendations, pollution fish kill investigations, applied research education and promotional work, commercial fishing studies and special investigations related to fisheries

-acquiring public access areas to fishing waters

Wildlife Resources Division

-provides opportunities for outdoor recreation and a good environment for wildlife on public and private lands

Law Enforcement Division

Formerly known as game wardens, Conservation Police Officers

-relate information on the recreation activities sponsored by the Department

-conduct programs designed to acquaint the public with their work

-educate and train persons in boating, hunting, or snowmobile safety

-assist other agencies in flood rescue work

INDIANA

Indiana State Board of Health

-certifies operators of wastewater treatment plants, and also of water treatment plants and distribution systems

-reviews and approves of plans for public water supply along with the enforcement of drinking water standards

-conducts statewide water quality control program with the cooperation of local and federal agencies

-reviews plans for municipal and industrial wastewater treatment facilities

-maintains a statewide stream sampling network

-provides staff and technical assistance to the Stream Pollution Control Board, and the Environmental Management Board

Environmental Management Board

-evolves and keeps constantly updated a comprehensive, long-term program for the state for the development and control of the environment

-evolves standards and develops regulations, and adopts standards and regulations to preserve, protect, and enhance the quality of the environment, to assure the accomplishment of the comprehensive long-term program

-procures compliance with its standards and regulations

-conducts a program of continuing surveillance and inspection of refuse disposal sites, public

water supplies, actual or threatened sources of environmental pollution by contamination, radiation, odor or noise
- encourages and assists local units of government in developing programs and facilities for air, water, radiation, odor, and noise pollution control, water or wastewater treatment, water resource development, and solid waste disposal.

Stream Pollution Control Board

The Board has operated under the general overview of the Environmental Management Board since its creation in 1972; regulations and programs of the Board are subject to the approval or concurrence of the Environmental Management Board.

The professional and support staffs for the Stream Pollution Control Board are staff and employees of the Indiana State Board of Health; however, the Stream Pollution Control Board exists as an independent administrative board and not as a part of the State Board of Health.

- adopts water quality standards, which specify requisite water quality for the protection of beneficial uses of the State's waters
- adopts other regulations needed to implement specific programs for the control and prevention of water pollution; such as the requirement of prompt reporting and clean-up of spills of oil and hazardous materials, the regulation of industrial liquid waste hauling, the regulation of construction and operation of sanitary landfills and refuse processing facilities, etc.
- investigates and evaluates sources of water pollution
- promotes adequate treatment facilities for all new and existing sources of water pollution and administration of the Federal/State grant program under the FWPCA for the construction of needed municipal wastewater treatment facilities
- reviews and approves of plans and specifications for proposed pollution abatement facilities
- administers the NPDES permit program for the control of all point sources discharges to State waters
- implements the Confined Feeding Control Law and the Refuse Disposal Act
- issues orders, subsequent to administrative hearings, for the enforcement of water quality standards and other regulations adopted by the Board and of NPDES and other permits or approvals issued by the Board. Where necessary, court actions for the enforcement of such orders and for injunctive relief in emergency situations are undertaken by the Board through the Indiana Attorney General

Department of Natural Resources

- has jurisdiction over all public and private waters in the State, as well as adjoining lands necessary for flood control purposes
- provides minimum standards for local zoning and management of lands which subject to periodic flooding
- approves of construction in floodways
- inspects maintenance and repair of dams, levees, dikes, floodwalls, and appurtenant works in, on, or along rivers, streams, and lakes
- establishes and maintains a natural scenic, and recreational rivers system
- supervices the harvest of fish and game resources
- administers the grant-in-aid portion of the Land and Water Conservation Fund Program
- develops and manages outdoor recreation and wildlife management facilities
- conducts the registration of all motor-boats operating on the waters of the State
- protects the waters and lands of the State against pollution and the loss or impairment of water resources

Indiana Port Commission

-created in 1961 to construct, maintain, and operate a public port on Lake Michigan, in cooperation with the Federal Government or otherwise, for the purpose of promoting the agricultural, industrial, and commercial development of the state, and to provide for the general welfare

-powers broadened, giving it authority to construct and operate a port on the Ohio River or the Wabash River, and to construct new canals or improve existing canals to connect the Indiana port with other waterways

-has the power to build or acquire and lease industrial facilities which "will increase the waterborne traffic into and out of the port."

Public Service Commission of Indiana

-a quasi-judicial agency

-regulates the rates and standards of service for investor owned water utilities

-has jurisdiction over the rates of municipal water utilities, but has no jurisdiction over the "practices" of such utilities, with regard to extensions of service territory, quality of service, or other practices which are governed solely by the municipality

-regulates the rates and standards of service for most rural water and sewage facilities, but has no jurisdiction over Regional Water and/or Sewage Districts which render water and/or sewage disposal services

State Planning Services Agency

-conducts the State's Coastal Zone Management Program

MICHIGAN

Department of Agriculture, State Soil Conservation Committee

-carries out the policy of the state to provide for the conservation of soil and soil resources and the prevention of soil erosion

-carries out responsibilities through locally organized soil conservation districts

Department of Commerce, Public Service Commission

-regulates gas, electric, telephone and water companies, and intrastate motor transportation to assure consumers of adequate services, at reasonable rates, from businesses which, by their nature, must be non-competitive

Department of Labor, State Board of Plumbing

-licenses plumbers

-supervises and inspects plumbing

-adopts and enforces minimum plumbing standards

Department of Natural Resources

-has responsibility for protecting and conserving the natural resources of the state

In 1973 the Department was reorganized and expanded to include all environmental protection agencies. Water resource functions are found primarily within four bureaus:

- Bureau of Environmental Protection
  - Division of Water Quality
  - Division of Environmental Services
  - Division of Environmental Enforcement
- Bureau of Land and Water Management
  - Division of Water Management
- Bureau of Renewable Resource Management
  - Division of Fisheries
- Bureau of Recreation
  - Division of Waterways

-guards against the pollution of lakes and streams

-fosters and encourages the protection and propagation of game and fish

-manages state parks, including the Mackinac Island and Michilimackinac units

-acquires, constructs and maintains harbors and channels

-grants harbor concessions

-regulates boating and water safety educational programs

Water Resources Commission

-concerned with the abatement and prevention of pollution of surface, underground and Great Lakes waters

-issues state-federal permits to control waste discharges under the National Pollutant Discharge Elimination System (NPDES); may establish
  pollutant restrictions and conditions in permits
  compliance schedules in permits
  monitoring requirements

and may require by rule and permit the preparation of pollution incident prevention plans and storage facilities to assure proper handling of critical pollutants

may hold hearing and conferences bearing on permit actions

Michigan State Waterways Commission

-acquires, constructs, and maintains recreational harbors, channels, docking, and launching facilities

-administers commercial docks in the Straits of Mackinac

The Division is financed exclusively from three forms of boating taxes: a) the marine fuel tax, b) 25% of boat registration fees, and c) the revenues from the operation of Division facilities.

Wilderness and Natural Areas Advisory Board

-makes recommendations for the dedication and administration of wilderness areas, wild areas and natural areas

-seeks cooperation and support of interested citizens and conservation groups

Department of Public Health

-approves plans and regulates public water supplies

-licenses well drillers

Water Well Drillers Advisory Board

-examines candidates for registration

-acts in an advisory capacity to the state health director on rules, regulations and construction codes

WISCONSIN

PUBLIC SERVICE COMMISSION

Engineering Division

-concerned with the technical, engineering aspects of utility operation, including adequacy of service, facilities and safety

-makes valuations of public utility plants

-conducts studies of adequacy of electric and gas supply

DEPARTMENT OF NATURAL RESOURCES

-provides an adequate and flexible system for planning and managing the protection, development and use of the water, air, forest, fish, game and other plant and wild animal resources of the state, and for the control of solid waste and refuse disposal

-reviews the natural resources programs of other state agencies and makes appropriate recommendations to the governor and the legislature

The field operations of the Department are under the direction of six district directors, each responsible for the total mission of the department in his district. The district directors report to the office of the secretary in Madison. The district boundaries coincide with the boundaries established for the eight administrative districts created by executive order in 1970. Advisory committees assisting the Natural Resources Board include, besides the citizen-elected Conservation Congress, groups on aquatic nuisance control, research, forest management, county forests, forest pest control, Great Lakes commercial fishery and outdoor recreation.

Water Resources Council

-advises the Department on setting of water quality standards and enforcement of water quality regulations

The PCB Advisory Council

-advises the Department and reviews proposed rules prescribing methods and providing sites and facilities for the disposal of PCBs

DIVISION OF ENVIRONMENTAL STANDARDS

Bureau of Water Quality

-develops water quality standards and methods of evaluating water quality

-plans and coordinates water quality survey and monitoring activities

-is responsible for the review of the planning, design, construction, and operation of public and private water supply systems, sewage treatment and industrial waste treatment systems

DIVISION OF RESOURCE MANAGEMENT

-plans and coordinates the development, protection and utilization of forest, fish and game resources, other wild plants and animals, and other outdoor recreation resources of the state

Bureau of Fish and Wildlife Management

-is responsible for planning and coordinating the maintenance and improvement of fish populations and habitat

-is responsible for planning and coordinating the management of Wisconsin wildlife resources on both public and private lands

Bureau of Parks and Recreation

-is responsible for planning and coordinating the acquisition, development, and operation of state parks

-is responsible for planning the recreational developments of other lands under the jurisdiction of the Department

DIVISION OF ENFORCEMENT

-plans and directs a coordinated program of law enforcement encompassing all department enforcement responsibilities, including environmental actions, fish and game violations, water management and zoning matters, air pollution control and solid waste management, park and recreation area responsibilities, forestry and other matters

Bureau of Law Enforcement

-is responsible for planning and coordinating the enforcement of laws and regulations relative to the protection, management and use of Wisconsin's natural resources

-is responsible specifically for the planning, coordination, and staff supervision of the enforcement of hunting and fishing regulations, the hunter safety, boating safety, snowmobile safety and law enforcement recruitment programs

-develops and supervices law enforcement training plans for the entire department with general guidance and coordination from the department training officer

Bureau of Water Regulations and Zoning

-is responsible for survace water levels and the design of dams and other structures in state waters

-plans and supervises shoreland zoning and floodplain regulation

Permits and Orders Section

-utilizes department surveillance and reporting systems, providing timely information on the status of and violation of laws, orders and permits

-informs appropriate personnel when public and private entities are not in conformance with existing permits and orders

STATE COASTAL ZONE COORDINATING AND ADVISORY COUNCIL

-provides policy direction for the coastal program and advises the Governor as to the progress and needs of the program

GOVERNORS TASK FORCE ON DROUGHT PLANNING

-is charged with the responsibility of coordinating the efforts of federal, state, and local agencies concerned with drought conditions in Wisconsin. The Governor requested that the Task Force develop legislation designed to assist in alleviating the serious drought-caused problems faced by the state.

WISCONSIN ENVIRONMENTAL EDUCATION COUNCIL

-is responsible for developing a state plan for environmental education programs, to:

a) assist in the broad coordination of environmental education activities in the state
b) implement other environmental education program activities required by the state statutes
c) recommend such changes in the statutes with respect to environmental education as the public interest may require

APPENDIX C

LOCAL AGENCIES

THE INDIANA EXAMPLE

SOURCE: STATE OF INDIANA

Board of County Commissioners

In general, the Board of County Commissioners is responsible for the administration of all county business. The Commissioners have many functions which impact upon the water resources of their particular county. These functions include:

Adopting ordinances: This includes the authority to adopt flood plan management zoning ordinances; ordinances to control the location, construction, or repair of all wells within the county; ordinances requiring persons who own or lease property outside the corporate limits of any city or town, which has buildings used for business or residential purposes, to connect to available sewer systems, and regulate the manner and method of disposal of domestic or sanitary sewage by private methods.

Serving with the county surveyor as members of the County Drainage Board.

The power to straighten or change the course, direction, or location of any stream or body of water, and to change any watercourse, or the flow of any stream or body of water within the limits of the county.

Appoint a County Plan Commission.

County Council

The financial powers of counties are placed in the County Council which serves as a check on the Board of County Commissioners. Therefore, the County Council is charged with the responsibility of appropriating all funds for use by the county and all of its officers.

The Council also has the exclusive power of fixing the rate of taxation for county purposes and for all other purposes where the rate not fixed by law is required to be uniform throughout the county, and impose the tax levy.

No sale or conveyance of any real estate of the county of a value of $1,000 or more, and no purchase by the county of any real estate of such value may take place, except pursuant to an ordinance of the council authorizing the sale or purchase and fixing the items and conditions.

Finally, the County Council has the exclusive power to authorize the borrowing of money for the county, but the total amount of county indebtedness may not exceed an amount equaling two percent of the assessed valuation of the county, less the total of all mortgage exemptions.

County Surveyor

The primary duties of the County Surveyor are to survey and keep records of all section corners throughout the county and supervise all civil engineering work of the county including construction and maintenance of drains and ditches, and also highways, bridges, and culverts except in counties where the Board of Commissioners assigns highway, bridge, and culvert construction and maintenance to the highway supervisor. The county Surveyor also serves as an ex-officio member of the County Drainage Board and supervises all legal ditch construction and maintenance.

County Drainage Board

The County Drainage Board is responsible for construction and maintenance of legal drains. Petitions for drainage construction are filed with the board which determines whether they are practicable and/or beneficial. The board also determines assessments against affected property owners, based on benefits they realize from the projects, and then, provided remonstrances are successful, the board can contract for drainage construction and sell bonds, when necessary, for financing. The county superveyor, which serves as the board's technical authority, makes necessary studies and prepared specifications for drains, and also supervises the construction.

City Common Council, Town Board

Indiana's cities are classified, according to their population, into five classes: First Class - over 250,000; Second Class - 35,000 to 249,999; Third Class - 20,000 to 34,999; Fourth Class - 10,000 to 19,999; and Fifth Class - 1500 to 9,999. Indianapolis is the State's only first class city.

The General Assembly in 1971 gave cities a new set of guidelines which govern the areas in which the common councils, or city councils as they are usually referred to, may operate. This legislation has become popularly known as the "home rule" bill, and in 1977 the legislature extended these guidelines to towns, except for the provisions dealing with the division of powers between executive and legislative branches. Therefore, all city councils and town boards have essentially the same basic powers and authority with respect to water resources. Some of these powers are:

Adopting ordinances regarding water, sewage, and general health. Including zoning ordinances concerning flood plan management;

*Establish, maintain, and control watercourses;

*Regulate the introduction of any substance into the water or onto the banks of the watercourse which endangers the public health, safety, or welfare or causes injury to property;

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*A city or town may exercise any of these powers within 10 miles of its corporate limits, but not beyond the county line of the county in which the city or town hall is located.

**A city or town may exercise any of these powers within 4 miles from its corporate limits.

Regulate any recreational or business use of a watercourse;

*Purify the water in watercourses;

*Establish wharfs on watercourses;

*Vacate or create a new watercourse;

Regulate the introduction of any substance into any subterranean stream or body of water in such a manner as to endanger the public health, safety, welfare, or cause injury to property;

**Establish, construct, maintain, control and operate public and municipal facilities such as sewers and sewage disposal systems and water works; and

Erect, purchase, or lease water works, gas works, electric light works, heatings, steam, and power plants for the purposes of providing such services to the public.

Board of Public Works

In 2nd, 3rd, 4th, and 5th class cities and towns, the agency responsible for public works has the following duties and powers which affect water resources:

Lay out and construct drains and sewers within the city and to a distance of four miles outside the city;

Construct and operate water works and sewage treatment works;

Erect levees and straighten water courses within the city and to a distance of four miles outside;

Drain or fill stagnant water pools within the city and to a distance of four miles outside;

Maintain and improve harbors, seawalks, docks, and channels and make shoreline improvements;

Supervise and control facilities for collection and disposal of refuse; and

Supervise the establishment by property owners of improvement districts.

In a 1st class city, or Indianapolis, the above functions are carried out by the Department of Public Works.

Parks and Recreation

The County Council may establish a Department of Parks and Recreation for the purpose of administering and conducting a recreation program. In second class cities, parks and other public recreation facilities are under the supervision of the Department of Public Parks which is administered by a Board of Park Commissioners appointed by the Mayor. In third and fourth class cities and cities of the fifth class having a population of more than 5,000, the Common Council is authorized to establish, by ordinance, a Department of Public Parks.

Regional Water and Sewage Districts

Any area in the State may be organized as a regional water, sewage, and/or solid waste district for one or more of the following purposes:

To provide a water supply for domestic, industrial and public use to users within and without the district;

To provide for the collection, treatment and disposal of sewage within and outside the district; and

To provide for the collection, treatment, and disposal of solid waste and refuse within and outside the district.

Petitions for the organization of a regional water, solid waste and/or sewage district must be filed in the Office of the Stream Pollution Control Board.

Drainage Maintenance and Repair Districts

When a public ditch or drain has been or is to be constructed, 20% of the real estate owners which own at least 20% of the land benefiting from the constructing of the ditch or drain may petition for the establishment of a drainage maintenance and repair district. Once the district is established, the appointed commissioners are empowered and authorized to hire all necessary labor, purchase all necessary material, and do all acts necessary and incident to the maintenance of the ditch and drain.

Conservancy Districts

Under the provisions of the Indiana Conservancy Act local land owners may petition the circuit courts for the establishment of conservancy districts that have the necessary legal authority and fund raising powers to construct, operate, and maintain works of improvement for solving water management and water resources problems. These districts may be found to accomplish one or more of the following purposes:

Flood prevention;

Improve drainage;

Provide for irrigation;

Provide for water supply, including treatment and distribution for domestic, industrial, and public use;

Provide for the collection, treatment, and disposal of sewage and other liquid wastes;

Develop forests, wildlife areas, and parks and recreational facilities where feasible in connection with beneficial water management.

Prevent the loss of top soil due to water erosion;

Store water for augmentation of stream flow; and

Operation, maintenance, and improvement of any existing work of improvement for water-based recreational purposes, or other work of improvement which could have been built pursuant to any of the above purposes.

The program and operation of the conservancy district may be financed by special benefit taxes levied on real property, the collection of assessments from lands which receive exceptional benefits, the receipt of funds from Federal or State government, the receipt of revenue from the sale of services of property, the collection of assessments for maintenance and operation of the works of improvement and borrowing from private or public sources.

Soil and Water Conservation Districts

Soil and Water Conservation Districts are established to encourage the development, improvement, and conservation of lands and water. A Board of Supervisors, which is assisted by technicians of the U.S. Soil Conservation Service, promotes the use of proper land treatment practices and sound farming techniques by the local landowners. The districts have active interests in the Federal watershed protection and flood prevention program. The districts also have authority to construct water control and management works, however, the districts do not have any eminent domain, taxing, or assessment powers.

County Plan Commission

The County Plan Commission, which is appointed by the County Commissioners, is empowered to:

Make surveys of the county's resources and make plans for their conservation;

Formulate and recommend adoption of plans for community betterment;

Cooperate with other departments and units of government in the preparation of a master plan for the development of the county, including long-range public works and financial programs;

Approve any proposed community subdivision lying outside the corporate limits of any city or town within the county; and

Administer a zoning ordinance for the unincorporated area which shall be duly adopted.

173

The County Plan Commission has jurisdiction within the unincorporated area of the county, however, any city or town may authorize the County Plan Commission to act as the city or town planning commission. The commission is also empowered to hire a secretary and other necessary employees.

City Plan Commission

The City Council may authorize the appointment of a City Plan Commission. These commissions have duties which are quite similar to those of the County Plan Commission. Their jurisdiction is restricted to the corporate limits plus a two mile fringe in some cases. Their authority consists of:

Formulate and recommend adoption of plans for the community's betterment;

Cooperate with other departments and units of government in the preparation of a master plan for the development of the city, and

Administer zoning ordinances.

The commission also has the power to establish its own rules and regulations within the statute, and to appoint a secretary and professional consultants whom it deems necessary for the fulfilling of its duties.

Town Plan Commission

The Town Board may authorize the appointment of a Town Plan Commission with duties and authority similar to the City Plan Commission listed above.

Area Plan Commission

The Area Plan Commission is appointed by the County Commissioners and legislative bodies of participating cities and towns to do unified planning. They have the authority to:

Make surveys of the area's resources and make plans for their conservation;

Formulate and recommend adoption of plans for community betterment;

Cooperate with other departments and units of government in the preparation of a master plan for the development of the area, including long-range public works and financial programs;

Approve any proposed community subdivision lying within the area of their jurisdiction;

Administer a zoning ordinance for the area which shall be duly adopted.

The Area Plan Commission has jurisdiction over the unincorporated area of a county, plus the participating cities and towns.

Metropolitan Planning Commissions

In two counties; Marion and Delaware, provision is made for the county and city within it (population of more than 65,000) to consolidate their planning operations by creating a bipartisan Metropolitan Planning Commission. By doing this the separate planning and zoning functions of the city and county plan commissions must cease and be exercised by this new agency. Therefore, the powers, functions, and duties of the Metropolitan Planning Commission include those assigned by existing laws to city plan commissions and county plan commissions.

Multi-County Planning Commissions

The County Commissioners of any contiguous counties have the power to set up multi-county planning commissions with the purpose of promoting orderly development of specific geographical areas.

Regional Planning Commissions

The County Commissioners in any region of the State may request that a regional planning commission be established. The commission may be reorganized from any multi-county planning commission which already exists there, and shall act in an advisory capacity only.

Councils of Governments

Counties can combine under the 1957 interlocal cooperation acts to form multi-county "Councils of Government". These regional agencies can have the same planning functions as other kinds of multi-county planning units.

Little Calumet River Basin Commission

The Little Calumet River Basin Commission was established in 1971 with the purpose of coordinating the efficient development of the water and related land resources of the Little Calumet River Basin.

Kankakee River Basin Commission

The Kankakee River Basin Commission's purpose is to coordinate the planning and development of the water and related land resources of the basin.

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Elaine lives on a small dune at the southern tip of Lake Michigan in Gary, Indiana. It follows that her favorite sport is swimming, and a close second is walking along the beach. She has two sons who share her interests in the environment. One is a geologist, and one is a photographer.

DRINKING WATER DECISIONS-- A COMPLICATED PROCEDURE

INTRODUCTION

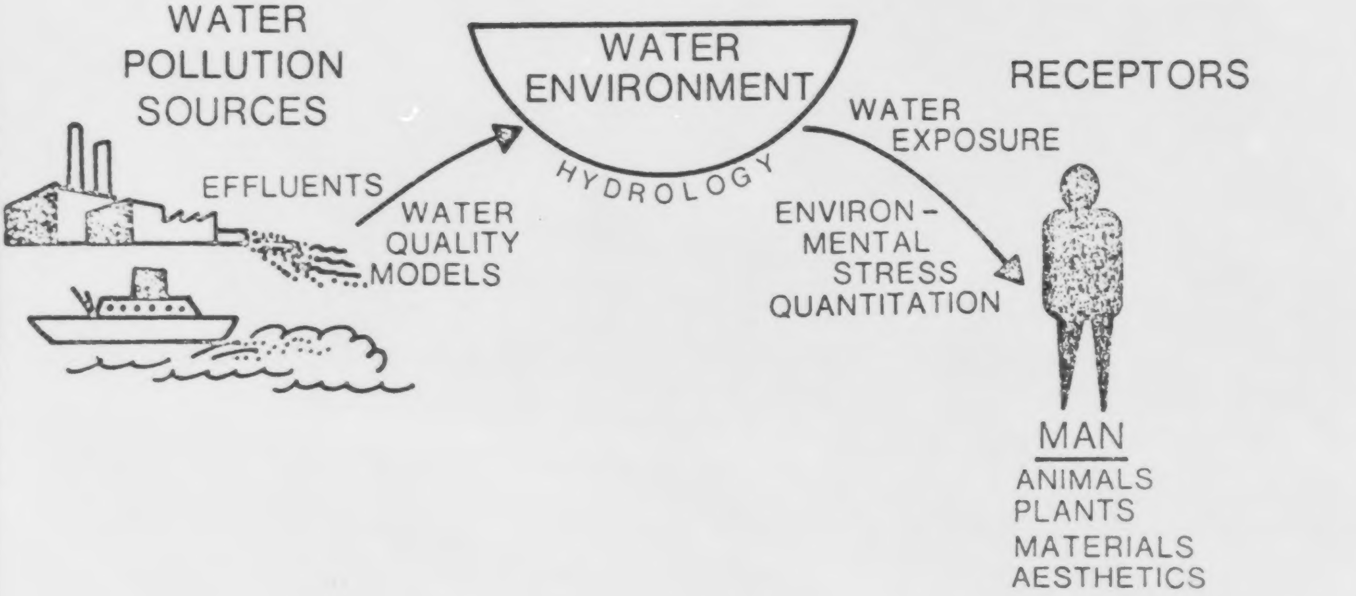
Although water covers most of the earth's surface, much of it is laden with salt. In 1977, at a United Nations water conference in Argentina it was pointed out that "95 percent of the world's water is contained in the seas. Of the 5 percent that is fresh, 4 percent is frozen in the polar regions. Thus, all the water in lakes and rivers, all the moisture in the atmosphere, the soil and vegetation, and all the water underground amounts to only one percent of the total." Lake Michigan, along with the other Great Lakes, contains 20 percent of the world's supply of fresh surface water. Take this amount from the surface water within the available one percent and you will have an idea of the value of our lake. As a source for drinking water, this value cannot be over estimated. As a source for swimming, boating, aesthetic satisfaction, it services our personal as well as economic needs.

Fresh water supplies, contaminated with human, animal or industrial waste, urban and argicultural runoff, and atmospheric fallout, pose a danger to external or internal body contact. There are beaches on the shores of Lake Michigan closed to prevent bodily water contact. Posted warning signs are indicative of the relationship between water quality and personal health. This chapter will focus on warning signs we are receiving on what we have come to take for granted--safe drinking water. Questions are being asked about the adequacy of supply even about the chemicals used to purify water sources.

RISK

Newspaper headings like the ones which appeared in the Wall Street Journal on January 25, 1978, "EPA Issues Proposals to reduce amounts of Cancer-Linked Substances in Water" and in the New York Times on April 9, 1978, "Safe U.S. drinking water is no longer a certainty" indicate a crisis in water quality and treatment.

Natural environmental pollutants are always present at background levels. There is no doubt that man adds to these levels with technological developments. All human activity carries some risk. We can attempt to minimize this risk by getting information so that we can make decisions consciously and intelligently. Chemical hazards in treated drinking water might be carcinogenic (cancer causing), mutagenic (genetic change causing), or tetratogenic (causing of malformation in the newborn). There is evidence of a correlation between cardiovascular disease and the softness/hardness of water and wh have made progress, but have not solved the problem of bacterial or viral contamination. We are concerned about these effects and recognize that there are indeed health consequences from these biological, physical, and chemical environmental stresses.


WATER POLLUTION SOURCES
EFFLUENTS
WATER QUALITY MODELS
WATER ENVIRONMENT
HYDROLOGY
RECEPTORS
WATER EXPOSURE
ENVIRONMENTAL STRESS QUANTITATION
MAN
ANIMALS
PLANTS
MATERIALS
AESTHETICS

EFFLUENTS (MASS/TIME)	CONCENTRATION (MASS/VOLUME OF WATER OVER SOME AVERAGING TIME)	EXPOSURE (TO RECEIVING WATER CONCENTRATION OVER PERIOD OF TIME)
EFFLUENT STANDARDS	WATER QUALITY STANDARDS	INGESTION, CONTACT

Figure I. Sources, receptors and the water environment.

STANDARDS

Standards are legal rules that set limits on impurities which may be hazardous to health. To protect the traveling public and to set guidelines for water supplies, the first national bacteriolocical water quality standards were set by the U.S. Public Health Service in 1914. Applied specifically to interstate water carriers, these standards were adopted on a formal or informal basis by some states. With the upgrading of standards and with more attention to sampling, monitoring, and maintenance of an adequate water distribution system, most individuals felt satisfied with the existing treatment of their drinking water supplies. In 1914, the U.S. Public Health Service established sampling procedures based on a community's population. These procedures also addressed potential hazards in the water distribution system since most of the outbreaks of illiness were being traced back to faculty plumbing, cross-connections, and post-contamination. Upgraded drinking water standards were adapted in 1942, and again in 1962, but it wasn't until 1974 (when the Safe Drinking Water Act was passed) that standards applied to all systems.

The 1962 standards endorsed by the American Water Works Association for the first time limited concentration of radioactivity and several chemicals including pesticides. The public health Advisory Committee noted that pollution of water supplies with such contaminants could become significant and urged that the problem be kept under close surveillance.

HEALTH AND AESTHETIC SIGNIFICANCE OF TRACE ELEMENTS AND COMPOUNDS

Occurrence in U.S. Water Supplies

Trace element or compound	Health or aesthetic effect	1962 USPHS drinking water standards limit, mg/1	Occurrence in 2,595 distribution samples, 1969, mg/1	
			Avg	Range
Alkyl benzine sulfonate (ABS)	USPHS limit gives a safety factor of 15,000; not highly toxic	0.5^a	0.05	0-0.41
Arsenic (as)	Serious systemic poison - 100 mg usually causes severe poisoning, is cumulative, and may cause chronic effects. Late evidence indicates tiny amounts may be beneficial	0.01^a 0.05^b	0.0001	< 0.03-0.10
Chloride (Cl^-)	Limit set for taste reasons	$250.^a$	27.6	< 1.0-1,950
Copper (Cu)	Body needs copper at level of about a mg/day for adults; not a health hazard except when large amounts are ingested	$1.^a$	0.13	0-8.35
Carbon chloroform extract (CCE)	At limit state, organics in water are not considered a health hazard	0.2^a	0.11	0.008-0.56
Cyanide (CN^{-2})	Rapid fatal poison, but limit set provides safety factor of about 100	0.01^a 0.2^b	0.00009	< 0.1-0.008
Fluoride (F^-)	Beneficial in small amounts; above 2,250 mg dose can cause death	$0.7-1.2^1$	0.32	< 0.2-4.40
Nitrate (NO_3)	Excessive amounts can cause methemoglobinemia (blue baby) in infants	45^a	6.3	< 0.1-127
Sulfate (SO_4)	Above 750 mg/1, usually has laxative effect	250^a	46	< 1.0-770
Zinc (ZN)	Zinc is beneficial in that a child needs 0.3 mg/kg day; 675-2,280 mg/1 may be an emetic	5^a	0.19	0-13.0
Barium (Ba)	Fatal dose is 550-600 mg as the chloride; it is a muscle (including heart) stimulant	1.0^b	0.034	0-1.55
Cadmium (Cd)	13-15 ppm in food has caused illness	0.01^b	0.003	< 0.2-3.94
Chromium (Cr^{+6})	Limit provides a safety factor. Carcinogenic when inhaled.	0.05^b	0.0023	0-0.079
Lead (Pb)	Serious, cumulative, body poison	0.05^a	0.013	0-0.64
Selenium (Se)	Toxic to both humans and animals in large amounts. Late research suggest small amounts may be beneficial	0.01^b	0.003	0-0.07
Silver (Ag)	Can produce irreversible, adverse cosmetic changes	0.05^b	0.008	0-0.03
Radium (Ra-226)	A bone-seeking,internal alpha emitter that can destroy bone marrow	$3\ pCi/1^c$	2.2pCi/1	0-135.9
Strontium (SR-90)	A bone-seeking, internal beta emitter	$10pCi/1^c$	<1.0pCi/1	0-20

FIG. 2

[a] Not to be exceeded where other more suitable supplies are, or can be made available.

[b] Excess constitutes grounds for rejection of the supply.

[c] Consult 1962 USPHS Drinking Water Standards for interpretation.

Source: J. Am. Water Works Assn., 63(11):728, 1971 by the American Water Works Association, Inc., 2 Park Avenue, New York, N.Y. 10016.

RECOMMENDED QUALITY CRITERIA GOALS OF LAKE WATER

At Chicago

At Chicago Intakes[a]

Parameter	Acceptable limits[b]	Permissible limits[d]
No. of coliform organisms/100 ml	< 200	2,500
DO, ppm	8	> 5
BOD, ppm	< 1.5	3
pH	8.2	9
		7.5
Chlorides, ppm	8[c]	15
Color	< 5	15
Total iron, ppm	< 0.10	0.2
Phenols, ppm	< 0.001	0.001
ABS, ppm	< 0.05	0.15
Total dissolved solids, ppm	165	185
Ammonia nitrogen, ppm	< 0.02	0.05
Sulfate, ppm	30	50

[a] Miscellaneous trace contaminants must meet USPHS limits.
[b] Annual average.
[c] Subject to readjustment.
[d] These limits must not be reached more than 12 days per year.

Source: J. Am. Water Works Assn., 57(7):841, 1965 by the American Water Works Association, Inc., 2 Park Avenue, New York, N.Y. 10016.

FIG. B38

CRITERIA

STANDARDS MAY OR MAY NOT BE BASED ON CRITERIA DEVELOPED FROM LITERATURE AND RESEARCH. WATER QUALITY CRITERIA ARE SCIENTIFIC JUDGMENTS ABOUT THE CONCENTRATION-EFFECT RELATIONSHIP OF A PARTICULAR WATER CONSTITUENT OR POLLUTANT. THEY PRESCRIBE A DESIGNATED CONCENTRATION OR VERBAL DESCRIPTION OF A CONSTITUENT THAT WHEN NOT EXCEEDED WILL PROTECT AN ORGANISM, AN ORGANISM COMMUNITY, OR A SPECIFIC USE OR QUALITY WITH AN ADEQUATE DEGREE OF SAFETY.

THE DEVELOPMENT OF CRITERIA BEGAN IN THE U.S. IN THE EARLY 1900'S. IT CONTINUED IN A SPASMODIC FASHION UNTIL 1966 WHEN THE SECRETARY OF INTERIOR COMMISSIONED AN APPOINTED NATIONAL TECHNICAL ADVISORY COMMITTEE. THIS GROUP IN 1968 PUBLISHED A COMPREHENSIVE REPORT ON WATER QUALITY REQUIREMENTS FOR WATER USE, SEPARATING CRITERIA INTO THE FOLLOWING CATEGORIES: AGRICULTURAL, INDUSTRIAL, RECREATIONAL, FISH AND WILDLIFE, AND DOMESTIC WATER SUPPLY.

THE DEVELOPMENT OF CRITERIA IS GROWING MORE RAPID AND GAINS INCREASING IMPORTANCE AS RESEARCH CONTINUES. IN EVALUATING DRINKING WATER QUALITY, TWO DEFINITIONS OF CRITERIA HAVE EVOLVED:

1) PERMISSIBLE CRITERIA ALLOWS PRODUCTION OF DRINKING WATER FROM A RAW WATER SOURCE, MEETING LIMITS OF SAFE DRINKING WATER STANDARDS AFTER TREATMENT.
2) DESIRABLE CRITERIA ALLOWS PRODUCTION OF DRINKING WATER WITH GREATER FACTORS OF SAFETY OR AT LESS COST THAN IS POSSIBLE WITH PERMISSIBLE CRITERIA.

THESE TWO DEFINITIONS MAY BE MODIFIED BY INTRACTIVE FACTORS SUCH AS DIET, SOCIAL HABITS, EXPOSURE, THAT ENTER INTO THE EVALUATION OF CRITERIA AND THE POSSIBLE RESULTING STANDARDS.

WE HAVE MANY AREAS OF IGNORANCE. WHICH VIRUSES STILL CAUSE DISEASE AND IN WHAT CONCENTRATIONS? WHAT SIZE PARTICULATES OR MICROSOPIC ORGANISMS PASS THROUGH FILTERS AND CAUSE DISEASE AND AFTER WHAT LENGTH OF EXPOSURE? HOW CAN WE IDENTIFY ALL HAZARDOUS CHEMICAL COMPOUNDS, DETECT THEM, ISOLATE THEM, AND DETERMINE WHAT QUANITIES MAY BE HARMFUL IN WHAT DOSES, AND OVER WHAT PERIODS OF TIME? HOW DOES ONE CHEMICAL BEHAVE IN THE PRESENCE OR ABSENCE OF OTHER MATERIALS? WILL THEY CANCEL EACH OTHER OUT OR PRESENT ADDITIONAL RISKS?

NOT ONLY ARE STANDARDS EVOLVING, BUT THE RESULTING CONTROL SYSTEMS ARE DIFFICULT TO ADMINISTER BECAUSE THEY ARE BASED ON UNCERTAINTIES OR RESULTS EXPECTED IN THE FUTURE. THE FIRST CLUB OF ROME LIMITS TO GROWTH REPORT, 1972 STATED "ANY POLLUTION CONTROL SYSTEM BASED ON INSTITUTING CONTROLS ONLY WHEN SOME HARM IS ALREADY DETECTED WILL PROBABLY GUARANTEE THAT THE PROBLEM WILL GET MUCH WORSE BEFORE IT GETS BETTER". A POSSIBLE SCHEMATIC THAT DESCRIBES THE DIFFICULTIES FACED IN TRANSLATING STANDARDS INTO CONTROL SYSTEMS IS SHOWN BELOW:

RELEASE OF POLLUTANT ------------ DELAY ------------ APPEARANCE IN
HARMFUL FORM ------------ RESEARCH ------------ CONTROL ------------
HARMFUL EFFECT DECREASES.

History of Water Health Relations

We have not just begun to search for answers. Ancient records indicate concern with a safe drinking water supply, as in this 4,000-year-old writing in Sanskrit; "It is directed to heat foul water by boiling and exposing to sunlight and by dropping seven times into it a piece of hot copper, then to filter and cool in an earthen vessel." The early Greek, Hippocrates, directed attention to the need to boil and strain rain water as a health measure. Sections of ancient aquaducts, still standing, remind us of efforts to bring adequate water supplies to urban populations. A correlation between disease and public water supplies was documented in 1854 by John Snow in London, England. He proved that cholera was caused by drinking water by separating sewage from the water source, getting the desired effect without knowing the cause. In Germany, after the germ theory was clearly established, Robert Koch stressed the importance of water filtration as a protection against cholera and other bacterial diseases. While in the United States during the mid-period of the 19th century the young city of Chicago was almost destroyed by its failure to establish an adequate water treatment system.

Lois Wille in her book, *Forever Open, Clear and Free*, said that in young Chicago,

> The Chicago Hydraulic Company, a private venture, built a pumping station and reservoir at Lake Street and Michigan Avenue-one of the first commercial enterprises on the city lakefront-and delivered water to the city through an intake pipe extending only 150 feet into the Lake. Human and animal waste drained into the Chicago River, emptied into Lake Michigan and came back through that intake pipe into the city's water supply. As a result, typhoid and cholera plagued the city. In 1854 about 1700 persons, more than 5 percent of the population, died in a cholera epidemic.

During the latter part of the last century, U.S. water engineers were experimenting successfully with sand filters in attempts to control epidemics of typhoid fever. By 1907 this filtration, accepted as standard by most cities, led to the elimination of most of the disease causing bacteria. In 1908 the filtering plant at the Chicago Stock Yards introduced chlorination as a disinfection means instead of filtration. As a result of these water treatments, i.e. filtrations, chlorination, or a combination of both, bacteria that caused most illnesses were under control by the early 20th century.

Water Treatment

Since early 20th century until this date conventional water treatment has historically put a major emphasis on detection and disinfection of microbiological contaminants and a secondary emphasis on gross hardness, water clarity, color, odor and taste. It differs from wastewater treatment in that one is a supply process while the other is a disposal process. Waste treatment removes pollutants from water discharged from municipalities, industries, etc., before it enters our waterways. Drinking water treatment has been necessary to further purify these waters so that they can be delivered

TO THE CONSUMER. ESSENTIALLY THE TREATMENT STEPS HAVE BEEN:

SEDIMENTATION

SEDIMENTATION, AS WITH WASTEWATER TREATMENT, IN WATER TREATMENT HAS BEEN THE PROCESS OF REMOVING SETTLEABLE MATERIALS. LARGE OR HEAVY PARTICLES ARE REMOVED EASILY WHILE LIGHT OR FINELY DIVIDED PARTICLES MUST FIRST BE TREATED SO THAT THEY FORM CLUMPS CALLED "FLOCS."

CHEMICALS NEED TO INDUCE THE GATHERING OF PARTICLES FOR REMOVAL ARE CALLED FLOCCULANTS. ALUMINUM SULFATE AND FERRIC CHLORIDE, COAGULANT ACIDS (POLYELECTROLYTES), ACIDS ALKALIS, EVEN CLAYS HAVE BEEN USED TO INDUCE COAGULATION WHICH IS THE CHANGE FROM LIQUID OR PARTIAL LIQUID TO A THICKENED MASS.

FILTRATION

FOR FURTHER CLARIFICATION, WATER HAS BEEN FILTERED THROUGH SAND, ANTHRACITE, DIATOMITE, OR CARBON MEDIUMS TO REMOVE FINE MATERIALS. UNDER CAREFULLY CONTROLLED CONDITIONS, THESE STAGES OF TREATMENT CAN REDUCE BACTERIAL COUNTS GREATLY AND MOST OF THE VIRAL CONTENT. ACCORDING TO THE NATIONAL RESEARCH COUNCIL STUDY IN 1977, CAREFUL SEDIMENTATION AND FILTRATION CAN ACTUALLY REDUCE VIRAL CONTENT BY UP TO 90-99 PERCENT.

DISINFECTION

SPECIFIC CONTROL OF BACTERIOLOGICAL QUALITY HAS BEEN ACCOMPOLISHED THROUGH DISINFECTION. VIRUSES, ALTHOUGH MORE RESISTANT TO THIS PROCESS THAN BACTERIA, CAN ALSO BE REDUCED. CHLORINE OR CHLORINE COMPOUNDS (SUCH AS CHLORIDE OF LIME OR SODIUM HYPOCHLORITE) HAVE BEEN USED FOR THIS PURPOSE BECAUSE OF THEIR RECORD OF LOW COST, DEPENDABILITY, EFFICIENCY, AND EASE OF HANDLING.

DISTRIBUTION

TREATMENT ENDS ONLY WHEN WATER THAT IS SAFE AND AESTHETICALLY DESIRABLE HAS BEEN DELIVERED TO THE TAP. NO ONE WANTS TO DRINK WATER THAT APPEARS DIRTY, CONTAINS PARTICLES, AND HAS A DISAGREEABLE ODOR OR IS UNPLEASANT TO THE TASTE. THE LEAGUE OF WOMEN VOTERS, IN THEIR 1973 FACTS AND ISSUES ON DRINKING WATER, COMMENTED:

> IN SOME WAYS THE DISTRIBUTION SYSTEM IS THE ACHILLES HEEL OF A PUBLIC WATER SUPPLY. EVEN IF THE WATER IS COMPLETELY SAFE WHEN IT LEAVES THE PURIFICATION PLANT, ALL SORTS OF THINGS CAN HAPPEN TO IT ON THE WAY TO THE CONSUMER'S TAP.
>
> *STORAGE
>
> WHEN THE WATER LEAVES THE TREATMENT PLANT IT MUST GO TO SOME KIND OF STORAGE FACILITY. THIS MAY BE A TANK OR TANKS OR ANOTHER RESERVOIR, BUT WHATEVER IT IS IT MUST BE CAREFULLY PROTECTED-COVERED AND LOCATED WHERE NO CONTAMINATED WATER CAN SEEP IN. LOCATING LOW TANKS ON A FLOODPLAIN, FOR EXAMPLE, WOULD BE UNWISE.
>
> *PRESSURE
>
> ADEQUATE PRESSURE AND TIGHT CONNECTIONS ARE IMPORTANT. PROBLEMS SOMETIMES ARISE WHEN A WATER SYSTEM IS EXTENDED. IF MAINS CANNOT CARRY AMPLE WATER FOR BOTH NEW AND OLD CONNECTIONS, PRESSURE IN REMOTE PARTS OF THE SYSTEM DROP.
>
> *PIPE, MAINS, AND LINES
>
> THE PIPES THEMSELVES SHOULD NOT INTRODUCE LEAD, ZINC, ASBESTOS OR HARMFUL CHEMICALS INTO THE WATER. MATERIAL USED TO CAULK JOINTS SHOULD NOT HARBOR BACTERIA. THE SYSTEM SHOULD HAVE NO DEAD ENDS WHERE WATER CAN STAGNATE AND

bacteria or other organism can grow. New lines should be disinfected before they are put into use. Cross-connections between drinking water supply pipes and pipes carrying other waters are a danger.

Warning Signals

Today, in addition to control of bacteria and viral contamination, there is increasing concern with micro-chemical and micro-physical subtances.

In 1962 Rachael Carson, in her book, Silent Spring, was one of the first to question the adequacy of water purity. She pointed to the increasing production of synthetic chemicals that accelerated after the 1940's, and wrote "It has now reached such proportions that an appalling deluge of chemical pollution is daily poured into the nation's waterways. When inextricably mixed with domestic and other wastes discharged into the same water, these chemicals sometimes defy detection by the methods in ordinary use by purification plants." Carson was accused by some segments of society of using emotionalism and scare tactics, but since her death, improved instrumental techniques have verified many of her pronouncements. Chemicals and toxics that may have possible effects on human health can now be analyzed at extermely small concentrations. Much of the research today concentrates on singling out these substances, identifying them, and testing them for acceptable levels.

An Environmental Defense Fund (a non-profit coaltion of scientist, lawyers, and others) released a report early in the 1970's establishing the first statistical link between high cancer mortality rates and drinking water. The fund-sponsored study compared cancer rates among people in Louisiana who used the Mississippi River as a water source, with rates in population who used other sources. Forty-six (46) potential carcinogenic or toxic organic chemicals were identified, revealing the potential threat of organic chemicals in drinking water. Other studies investigating the possible role of low-level carcinogens in drinking water were begun by the National Cancer Institute following the Environmental Defense Fund initiative.

Legislation

Evidence that potential health hazards were not being removed by conventional water treatment and that some were perhaps being caused by that very treatment, prompted Congress to pass the first comprehensive drinking water legislation. Applicable to all public drinking water systems (with at least 15 service connections or serving over 23 persons), the Safe Drinking Water Act was signed into law December, 1974, to be effecttive December, 1976.

Interim Primary Standards to protect human health were promulgated in 1975 to take effect in 1977. Maximum contaminant levels, set for coliform bacteria, arsenic, barium, cadmium, chromium, fluoride, lead, mercury, nitrate, selenium, silver, six pesticides, and radionuclides were based on the Public Health Service Standards of 1962. Maximum contaminant level refers to the highest permissible level of contaminant in drinking water, delivered to the consumer's tap. Secondary standards designed to protect public welfare apply to taste, odor, and appearance and were promulgated as guidelines, and not as regulations.

Under consideration were standards for four major types of organic chemicals, all of which are suspected as possible health hazards: natural products of decomposition, products of chlorination and decomposed materials in raw water, organic chemicals from point sources, and organic chemicals from nonpoint sources, organic chemicals merited special additional consideration based on the 1969-1970 Community Water Supply Study, an evaluation of 969 community water supply systems conducted by the Department of Health, Education and Welfare. In addition, the EPA National Organics Reconnaissance Survey (NORS) in 30 cities (1974) throughout the nation revealed that haloform compounds were below the limits of detection in raw water. Concentrations of these compounds, specifically trihalomethanes were higher as water moved through the disinfection process, through the distribution process, to the tap. In a follow up NORS in 1975 throughout Region V., the same conclusions were reached. Communities showing the highest levels of contamination tool water supplies from polluted river sources like the Mississippi and Ohio Rivers. Whiting, Indiana, Richfield, Minnesota, Waterford Township, Michigan, and Jackson, Michigan were listed as having the best water quality. It is interesting that Whiting, a city that uses southern Lake Michigan as a water source, in 1941 implemented ozone treatment to deal with phenol emitted by local industries. Ozone, produced by discharging electric sparks in the air, is one of the alternative suggested to decrease the use of chlorine in drinking water treatment facilities.

Under the Safe Drinking Water Act, designated water systems were required to submit samples of raw and treated water to the Environmental Protection Agency for analyses. A research program as well as the National Organic Monitoring Services instituted to answer the following questions:

1. What are the effects of commonly occurring organic compounds on human health?
2. What analytical procedures should be used to monitor finished drinking water to assure that Primary Drinking Water Regulations dealing with organics are met?
3. Because some of these organic compounds are formed during water treatment, what practices are required to minimize the formation of these compounds in treated water?
4. What treatment technology must be applied to reduce contaminant levels to concentrations specified in the Primary Drinking Water Regulations?

Robert Norris of the Environmental Defense Fund charged that the Interim Standards were inadequate and announced the filing of a suit against the Environmental Protection Agency in the U.S. Circuit Court of Appeals, District of Columbia. The suit asked the court to order the EPA to include standards on organic content, limits on toxic substances, and improved treatment systems and monitoring. The U.S. EPA acknowledged that the Interim Standards were just an initial step. The federal agency had contracted with the National Academy of Science for and in-depth study so these Interim Standards could be amended to protect public health. The U.S. EPA continued surveys throughout the country to gain information about the prevalence and sources of organic chemicals.

Conclusions

Prior to 1977, enough information was collected from EPA surveys and monitoring data so that specific conclusions could be reached by the Council of Environmental Quality. Both the CEQ 1977 Report released in 1978 and the National Academy of Science Study Drinking Water and Health mandated by the Safe Drinking Water Act and carried out by the National Research Council in 1977 identify these risks:

1. Bacteria often rise above levels considered safe for drinking water supply and far above safe swimming levels.
2. Chlorinated organic compounds are numerous among the known and suspected carcinogens found in drinking water.
3. There is confirmation that death rates from cardiovascular disease tend to decrease as the "hardness of water increases."

Control of Bacteria

After the water-borne disease rate declined sharply we became complacent. But renewed, reported, and unreported outbreaks of bacterial related water-borne disease since 1969 jolted us into the realization that the task is not finished. "In 1975, more than 10,000 cases of water-borne enteric (intestinal) diseases were reported, but in only about 10 percent of these cases were causal agents identified. There are reasons to believe many cases go unreported."

*Bacteria as Indicators are used as indicators of disease. The coliform bacteria group, found in the intestines of man and animals. The U.S. Public Health Service 1962 Drinking Water Standards and the Safe Drinking Water Primary Standards limit the number of coliforms for drinkable water to less than one (1) coliform colony per 100 mililiters of water examined in any one month, or 40 coliforms per gallon (1,000 coliforms per 100 ml criteria is used for body-contact swimming and boating). The 1 per 100 ml standard does not preclude the possibility of intestinal infection but it serves as a guide. The presence of the coliform, which may not be dangerous in itself, does indicate that the water may harbor disease carrying bacterial pollutants. The presence of fecal coliform indicates recent and potentially dangerous pollution. The presence of other coliform organisms (found in soil, sewage, water) indicates less recent pollution.

Chlorinated Organic Compounds

Chlorination has been one of the basic tents of water treatment. When chlorine combines with natural organic matter, such as decaying vegetation, chemicals such as chloroform and bromoform are created. Chloroform and bromoform are in a family of compounds that are classified as TRIHALOMETHANES. This family of chemicals has been linked with bladder and intestinal cancer by the National Cancer Institute. In a letter dated April 26, 1978, written to U.S. EPA Administrator Douglas Costle, a spokesman for the National Cancer Institute wrote that although tests were not conclusive "on a weight of evidence basis, one should have a high index of suspicion." After the National Academy of Sciences Study clearly identified chloroform as a health hazard, the EPA proposed a maximum contaminant level (MCL) of 100 parts per billion parts of water for to organic contamination. The table taken from the Environment Midwest EPA Region V, June 1978, (FIG. 4) shows that communities receiving water supply from Lake Michigan are rated N showing no contamination of significance. The Environment Midwest magazine stated that sources named as likely to receive "automatic" variance from GAC include deep aquifers, protected watersheds, and the Great Lakes. Groups such as the American Water Works Association and the Coalition for Safe Drinking Water are actively challenging these regulations as too costly and too experimental. In spite of European experience cited by the EPA, many water engineers feel the GAC method is unproven and unwarranted. They request that no single treatment technique be specified until adequate scientific data is accumulated and the financial impact is assessed. There is little disagreement on the need to adopt the National Academy of Sciences recommended concentration on water for 23 known carcinogenic compounds. However, the controversy over chlorination is now raging, because as yet its disinfection capability cannot be matched.

Hard Water/Soft Water Cardiovascular Linkage

In addition, where water treatment plants soften the water, they remove calcium and magnesium. There is causal evidence that a level of hardness may offer protection from cardiovascular disease. Water is classified as hard when it contains more than 75 mg/1 (parts per million) of calcium carbonate. Lake Michigan water hardness averages 135 parts per million as calcuim carbonated. It is the calcuim and magnesium, lacking in soft water, that affords the protection against lipid deposits of cholesterol in arteries, and has anticoagulant properties that limit blood clot formation. The World Health Organization and the International Atomic Energy Agency has recommended international studies on this association between water and heart disease. Information from the National Academy of Science Study of 1978 adds that soft water tends to be more corrosive than hard water: as a result certain trace metals are found in higher concentration in soft than in hard water: much testing is needed before actual true risk calculations can be made.

INITIAL RATINGS:

REGION V WATER SYSTEMS WITH POPULATIONS OF 75,000+

STATE/CITY	COUNTY	POPULATION	RATING*
Illinois			
Arlington Hts.	Cook	75,000	N
Aurora	Kane	75,000	N
Belleville (E. St. Louis)	St. Clair	80,500	P
Champaign	Champaign	122,424	N
Chicago	Cook	4,520,000	N
Decatur	Macon	91,018	P
East St. Louis	Madison	79,583	P
Evanston	Cook	83,000	N
Joliet	Will	80,000	N
Peoria	Peoria	170,000	N & P
Rockford	Winnebago	150,000	N
Springfield	Sangamon	125,000	P
Rend Lake, I.C.	Franklin	124,000	P
Indiana			
Evansville	Vanderbaugh	150,000	P
Fort Wayne	Allen	180,000	P
Gary-Hobart	Lake	250,000	N
Hammond	Lake	108,000	N
Indianapolis	Marion	608,000	P & N
Muncie	Delaware	87,000	P
South Bend	Elkhart	125,000	N
Terre Haute	Vigo	77,338	P & N
Michigan			
Ann Arbor	Washtenaw	99,797	P & N
Detroit Metro	Wayne	1,490,000	P & N
Van Buren Township	Wayne	94,400	Detroit
Dearborn	Wayne	104,300	Detroit
Dearborn Hts.	Wayne	80,900	Detroit
Flint	Genesee	193,317	Detroit
Livonia	Wayne	112,300	Detroit
Pontiac	Oakland	86,400	Detroit
Royal Oak	Oakland	84,600	Detroit
St. Clair Shores	Macomb	89,400	Detroit
Warren	Macomb	184,800	Detroit
Westland	Wayne	90,000	Detroit
Grand Rapids	Kent	208,000	N & P
Kalamazoo	Kalamazoo	90,000	N
Lansing	Ingham	131,546	N
Saginaw	Saginaw	91,850	N

*P - Potential for significant contamination from organic chemicals in drinking water.

N - No contamination of significance.

FIG. 4

INITIAL RATINGS (CONT.)

STATE/CITY	COUNTY	POPULATION	RATING*
Minnesota			
Duluth	St. Louis	113,790	N
Minneapolis	Hennepin	430,000	P
Oakdale Utility (St. Paul)	Hennepin	371,372	P
Ohio			
Akron	Summit	354,800	P
Canton	Stark	158,000	N
Cincinnati	Hamilton	850,000	P
Cleveland	Cuyahoga	1,800,000	P
Columbus	Franklin	704,000	P & N
Dayton	Montgomery	370,000	P
Elyria	Lorain	90,000	P
Greater Northridge	Montgomery	81,000	N
Hamilton	Butler	80,000	N
Lorain City	Lorain	85,000	P
Montgomery County	Montgomery	120,000	N
Springfield	Clark	88,000	N
Toledo	Lucas	455,000	P
Warren	Strumbull	80,000	P
Youngstown	Strumbull	23,950	P
Wisconsin			
Green Bay	Brown	87,809	N
Kenosha	Kenosha	78,805	N
Madison	Dane	172,005	N
Milwaukee	Milwaukee	709,537	N
Racine	Racine	95,162	N

*P - Potential for significat contamination from organic chemcials in drinking water.

N - No contamination of significance.

Testing

Two types of testing are possible to assess health risks. Data can be obtained from epidemiological studies (information directly applicable to human populations). Data must be obtained to identify cause of danger, to isolate the cause, if it is a chemical in use, to look at alternatives, to test alternatives, or to weight the balance between risk and benefits.

Laboratory studies involve a relatively small number of animals placed under standardized conditions and exposed to pollutants at known concentrations. Information on high risks related to individual pollutants can be obtained from effects on animals. This information can be compared to possible human exposure, and in general will have to be relied on to assess human risk. Observations suggest that small animals that are rountinely used for toxic testing are often more resistant than man. Man with many more cell divisions has a greater opportunity to develop neoplastic change (abnormal growth). Also, healthy specimans are chosen for animal experiments, while the human population contains many persons susceptible because of illness, age or deprivation. We are exposed to a variety of toxic agents in the air, in food, as well as in the water, and we have genetic variability to infection. The National Research Council concludes, "this means that there can be no totally safe exposure to a particular carcinogen, nor can the term 'margin of safety' have any meaning. Any dose of a carcinogen must be considered to be associated with a risk, and even if that risk is vanishingly small, it must be estimated."

Public Policy

Public policy issues are raised by the uncertainties that are in fact a part of testing Procedures. Those who would disagree with the setting of no-level standards for toxics, point to immune mechanisms that may be sufficient to stop or reverse ill health effects. This paper has very briefly addressed only some of the water-human health questions to be resolved by scientists, physicians, legislators, engineers, and the public. Many disciplines need to be involved in this gigantic task if we are to continuously improve human health-water relationships. The search for final evidence on risk and befefits will include research to establish criteria, laws motivating setting of standards, and an understanding on the part of the public to assure implementation of regulations. If this search does not continue we may be generating higher rates of morbidity and mortality while we wait.

SOME LAKE MICHIGAN CONTAMINATION PATHWAYS:

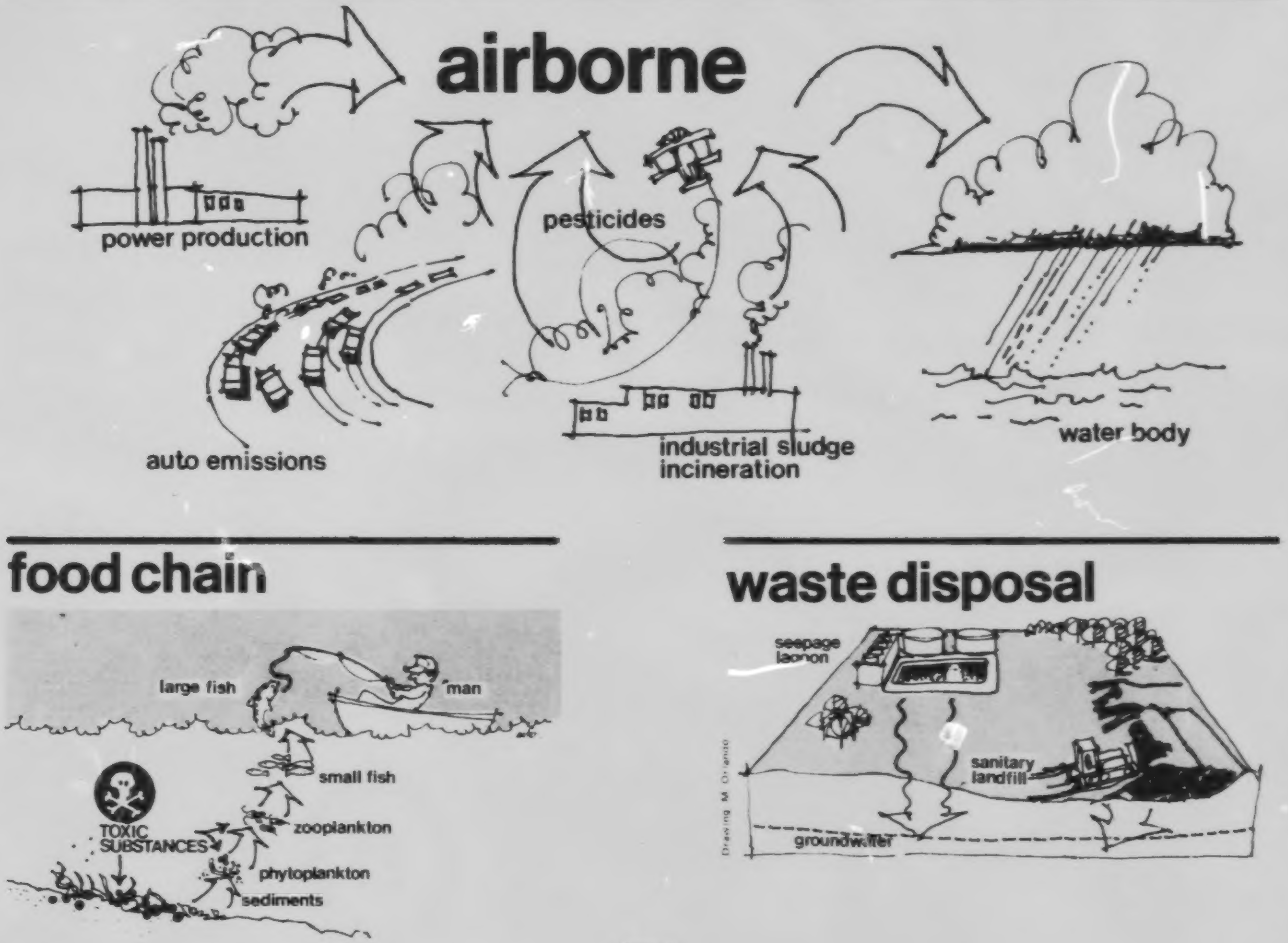

airborne
power production
auto emissions
pesticides
industrial sludge incineration
water body
food chain
large fish
man
small fish
zooplankton
TOXIC SUBSTANCES
phytoplankton
sediments
waste disposal
seepage lagoon
sanitary landfill
groundwater
Drawing M. Orlando

Figure 5

From Great Lakes Basin Communicator, September 1978

"PEOPLE AROUND LAKE MICHIGAN MAY BE FACING DRINKING WATER HAZARDS FROM FORMS OF POLLUTION THAT HAVE NOT EVEN BEEN IDENTIFIED."

THIS IS BECAUSE WE ARE NOW SEEING THE EFFECTS OF TWENTY OR THIRTY YEARS' EXPOSURE BEGINNING IN THE LATE 1940'S, BEFORE THE PRODUCTION OF SYNTHETIC ORGANIC CHEMICALS BEGAN ITS TREMENDOUS GROWTH. SINCE THERE HAS ALMOST CERTAINLY BEEN CONTINUING A SHARP INCREASE IN EXPOSURE TO THE PRODUCTS AND RESIDUALS OF THIS INDUSTRY OVER THESE YEARS, EVEN IF MORBIDITY AND MORTALITY ARE ONLY LINEARLY RELATED TO EXPOSURE, WE CAN EXPECT NONLINEAR INCREASES IN THESE MEASURES OF EFFECT. ON THE OTHER HAND, IT SIMPLY DOES NOT SEEM POSSIBLE TO REJECT OUT OF THE HAND THE POSSIBILITY THAT THE EFFECTS OF DOING NOTHING NOW WOULD BE QUITE SMALL. HERE WE HAVE THE MAKING OF THE MOST DIFFICULT AND CONFUSING POLICY DEBATE.

Footnotes

1. Lois Wille 1972, Forever Open, Clear and Free, Henry Regency Co., Chicago, Illinois p. 24.

2. "Resources for the Future," Resources, no. 60 (September-November 1978).

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JOANNE WESTPHAL

GLOSSARY

ABSENT: the most sensitive analytical procedure in Standard Methods (or other approved procedure) does not show the presence of the subject constituent.

ADVANCED WASTEWATER TREATMENT (AWT): a process that usually follows secondary treatment which removes large concentrations of nutrients and dissolved suspended solids.

DESIRABLE CRITERIA: those characteristics and concentrations of substances in the raw surface waters which represent high quality water in all respects for use as public water supplies. Water meeting these criteria can be treated in the defined plants with greater factors of safety or at less cost than is possible with waters meeting permissible criteria.

HOLDING TANK: a device (usually an underground drum) that is used to store wastewater until it can be transported to a wastewater treatment plant.

PERMISSIBLE CRITERIA: those characteristics and concentrations of substances in raw surface waters which will allow the production of a safe, clear, potable, aesthetically pleasing, and acceptable public water supply which meets the limits of Drinking Water Standards after treatment. This treatment may include, but will not include more than, the processes described above.

PRIMARY TREATMENT: 1) the first major (sometimes the only) treatment in a wastewater treatment works, usually sedimentation. 2) The removal of a substantial amount of suspended matter but little or no colloidal and dissolved matter.

RAW WATER: 1) untreated water; usually the water entering the first treatment unit of a water treatment plant. 2) water used as a source of water supply taken from a natural or impounded body of water, such as a stream, lake, pond, or underground aquifer.

SECONDARY WASTEWATER TREATMENT: the treatment of wastewater by biological methods after primary treatment by sedimentation.

SEPTIC TANK: an on-site wastewater disposal system composed of a settling tank and perculation field.

VIRTUALLY ABSENT: this terminology implies that the substance is present in very low concentrations and is used where the substance is not objectionable in these barely detectable concentrations.

WASTEWATER: the spent water of a community.

WASTEWATER FACILITIES: the structures, equipment, and processes required to collect, carry away, and treat domestic and industrial wastes, and dispose of the effluent.

WASTEWATER TREATMENT: any process to which wastewater is subjected in order to remove or alter its objectional constituents and thus render it less offensive or dangerous.

WATER QUALITY: the chemical, physical and biological characteristics of water with respect to its suitability for a particular purpose.

WATER STANDARDS: definitions of water quality established as a basis of control for various water use classifications.

WATER SUPPLIES AND WASTEWATER TREATMENT

INTRODUCTION

Water is a relatively plentiful resource. The world's supply consists of about 326 million cubic miles of water (Table 1). Unfortunately, less than 0.3 percent of our water resources is fresh water; most of this water is contained in the upper underground strata and in streams, rivers, and lakes. This 0.3 percent serves as the normal source for municipal, agricultural, and industrial supplies.

TABLE I -- DISTRIBUTION OF THE EARTH'S WATER RESOURCES (Lvovitch, 1972).

LOCATION	WATER VOLUME 10^{15} GAL.	PERCENT OF TOTAL
World Oceans	362,000	94.2
Glaciers and Ice Caps	6,350	1.65
Lakes	60.5	0.016
Soil Moisture	21.6	0.006
Atmospheric Vapor	3.7	0.001
River (Channel) Waters	0.32	0.0001
Total Underground	15,800	4.13
Groundwater Less than 0.5 miles down	(1,160)	(0.28)

In 1970 it is reported that the U.S. consumed 320 billion gallons of water per day. This water was taken up and used for a variety of purposes. Some of the water was eventually returned to rivers and streams, and some was consumed--that is, it was evaporated or became a part of a product or process. Therefore, it was not readily available for reuse. Table II indicates the use of water in the U.S. in 1965.

TABLE II. ESTIMATED WATER USE AND PROJECTED REQUIREMENTS, BY REGIONS, UNITED STATES (WATER RESOURCES COUNCIL, 1968).

(Million gallons daily)

Region	Used 1965	Projected Requirements 1980	Projected Requirements 2000	Projected Requirements 2020	Used 1965	Projected Requirements 1980	Projected Requirements 2000	Projected Requirements 2020
	Withdrawals				Consumptive Use			
North Atlantic.	37,467	54,920	113,860	236,290	2,023	2,870	4,960	8,490
South Atlantic-Gulf . . .	20,560	53,130	87,440	130,190	2,695	3,395	5,655	8,265
Great Lakes	25,119	47,893	96,594	190,960	1,199	1,831	3,183	5,484
Ohio	26,255	41,749	65,109	90,163	1,134	1,619	2,539	3,623
Tennessee	5,767	12,252	13,877	18,106	331	572	834	1,132
Upper Mississippi	3,179	14,800	30,587	41,266	770	1,103	1,778	2,624
Lower Mississippi	5,571	12,816	27,967	39,442	1,470	3,012	4,453	6,251
Souris-Red-Rainy	391	936	2,002	2,758	77	215	494	544
Missouri	19,344	23,264	27,876	31,572	10,554	13,160	14,979	16,378
Arkansas-White-Red . . .	9,410	17,279	25,336	31,589	5,874	8,482	10,587	12,329
Texas-Gulf	16,410	29,080	57,330	92,640	7,289	9,435	10,890	12,300
Rio Grande	7,289	8,330	9,510	11,680	4,403	4,676	4,991	5,466
Upper Colorado	4,017	5,675	6,575	6,725	1,982	2,700	3,100	3,140
Lower Colorado	6,913	8,497	8,428	8,889	3,448	4,075	4,645	5,310
Great Basin	5,115	7,055	7,550	7,800	2,253	3,299	3,562	3,776
Columbia-North Pacific .	29,631	41,407	90,135	156,735	10,521	13,581	17,325	21,616
California	37,300	56,290	120,510	244,760	20,944	29,205	32,660	38,190
Alaska	162	535	901	4,206	12	50	96	184
Hawaii	1,597	2,658	4,698	8,537	533	728	1,000	1,368
Puerto Rico	1,120	4,010	8,325	13,730	270	360	475	615
Total	269,617	442,626	804,610	1,368,088	77,782	104,418	128,206	157,085

THE UNITED STATES WITHDRAWS AND CONSUMES LARGE AMOUNTS OF FRESH WATER EACH DAY. TABLE II LISTS THE ESTIMATED WATER USE AND PROJECTED DEMANDS BY REGIONS IN THE UNITED STATES. NOT ALL OF THIS WATER IS LOST FROM THE HYDROLOGIC CYCLE--THAT IS, SOME OF THE WATER EVENTUALLY RETURNS TO RIVERS AND STREAMS VIA OUTFLOW PIPES, STORM SEWERS, AND DRAINS. BUT AN INCREASINGLY LARGE AMOUNT IS BEING CONSUMED--THAT IS, IT IS BECOMING A PART OF A PRODUCT OR PROCESS AND THEREFORE, IS NOT READILY AVAILABLE FOR REUSE. IT IS THIS AMOUNT OF WATER THAT HAS SCIENTISTS CONCERNED. ALREADY VARIOUS REGIONS OF THE NATION ARE EXPERIENCING WATER SHORTAGES. FIG. 1 SUMMARIZES EMERGING WATER MANAGEMENT PROBLEMS FOR VARIOUS PARTS OF THE U.S. (WATER RESOURCES COUNCIL, 1968). SOME EXPERTS SUGGEST THAT 615 BILLION GALLONS/DAY WILL BE THE MAXIMUM AMOUNT OF FRESH WATER THAT CAN BE TAKEN UP AND

	Adequacy of annual natural runoff	Ground-water storage depletion	WATER QUALITY				Flood damages	Water-shed lands	Beach, shore, and riverbank erosion	Wetlands
			Wastes	Heat	Salinity	Sediment				
North Atlantic	▲	▲	△	△	●	▲	▲	▲	○	○
South Atlantic-Gulf	●	▲	○	▲	●	○	○	○	△	△
Great Lakes	▲	●	△	△	●	▲	●	●	▲	▲
Ohio	▲	●	○	○	●	▲	○	▲	●	●
Tennessee	●	●	▲	▲	●	▲	▲	▲	●	●
Upper Mississippi	▲	●	○	○	●	▲	○	▲	○	○
Lower Mississippi	●	●	▲	●	●	△	○	○	○	○
Souris-Red-Rainy	○	●	▲	●	▲	●	○	●	▲	○
Missouri	○	○	▲	▲	▲	○	△	○	○	○
Arkansas-White-Red	○	△	▲	●	△	○	○	○	△	○
Texas-Gulf	○	△	○	▲	○	○	▲	○	○	○
Rio Grande	△	△	○	●	△	△	▲	○	▲	●
Upper Colorado	△	●		●	▲	○	●	▲	●	●
Lower Colorado	△	△	○	●	△	△		○	▲	●
Great Basin	△	▲	○	●	▲	▲	●	▲	●	▲
Columbia-North Pacific	▲	▲	▲	○	●	●	○	▲	▲	○
California	○	○	○	▲	○	▲	○	○	○	▲
Alaska	●	●	▲	●	●	●	▲	●	○	▲
Hawaii	●	▲	▲	●	●	●	●	▲	○	●
Puerto Rico	●	●	▲	●	●	○	●	○	▲	●

● - Minor problem in some areas

○ - Major problem in some areas or moderate problem in many areas.

▲ - Moderate problem in some areas or minor problem in many areas.

△ - Severe problem in some areas or major problem in many areas.

FIGURE 1. SUMMARY OF EXISTING AND EMERGING REGIONAL WATER MANAGEMENT PROBLEMS (WATER RESOURCES COUNCIL, 1968).

UTILIZED IN THE UNITED STATES BASED ON ANNUAL RAINFALL AND RUNOFF DATA. AND AS WATER SUPPLIES DIMINISH, INCREASED COMPETITION AMONG USERS CAN BE EXPECTED (TABLE III) AND PRIORITIES WILL HAVE TO ULTIMATELY BE ESTABLISHED.

WATER QUALITY

THE PROBLEM OF WATER SUPPLY IS NOT THE ONLY PROBLEM FACING AMERICANS CONCERNING WATER. THE WHOLE QUESTION OF WATER QUALITY IS ANOTHER ISSUE. PREVIOUS SPEAKERS HAVE ALREADY TOUCHED UPON THE CHEMICAL AND BIOLOGICAL CHARACTERISTICS OF WATER POLLUTION. BUT WHAT CHARACTERISTICS OF WATER MAKE IT SUITABLE AS A RAW MATERIAL FOR AGRICULTURAL, INDUSTRY,

TABLE III. U.S. WATER WITHDRAWALS AND CONSUMPTIVE USES (PETZ, 1976).

	1980		2000	
PURPOSE	GROSS WITHDRAWALS	CONSUMPTIVE USES	GROSS WITHDRAWALS	CONSUMPTIVE USES
IRRIGATION	167.0	104.5	184.5	126.3
MUNICIPAL	23.6	3.7	42.2	5.5
MANUFACTURING	101.0	8.7	229.2	20.8
MINING	2.7	0.6	3.4	0.7
STEAM--ELECTRIC POWER	258.9	1.7	429.4	2.9
	558.8	119.2	888.7	156.2

TABLE IV. QUALITY REQUIREMENTS OF WATER AT POINT OF USE BY THE TEXTILE INDUSTRY[A] (EPA, 1973).

CHARACTERISTIC	TYPICAL MAXIMUM RANGES
IRON, MG/L FE	0.0 - 0.3
MANGANESE, MG/L MN	0.01 - 0.05
COPPER, MG/L CU	0.01 - 5
DISSOLVED SOLIDS, MG/L	100 - 200
SUSPENDED MATTER, MG/L	0 - 5
HARDNESS, MG/L AS $CaCO_3$	0 - 50
COLOR, UNITS	0 - 5
TURBIDITY, UNITS	0.3 - 5
SULFATE, MG/L	100
CHLORIDES, MG/L	100
ALKALINITY, MG/L AS $CaCO_3$	50 - 200
ALUMINUM OXIDE, MG/L Al_2O_3	8
SILICA, MG/L SiO_3	25
ORGANIC GROWTHS	ABSENT

[A] WATER QUALITY PRIOR TO ADDITION OF SUBSTANCES USED FOR INTERNAL CONDITIONING.

POWER PRODUCTION, AND CONSUMPTION? THE ANSWER IS AS VARIABLE AS THE USES TO WHICH WATER IS EMPLOYED.

IN GENERAL, SPECIFIC USES HAVE SPECIFIC RAW SURFACE WATER CRITERIA WHICH ALLOWS AN ENGINEER TO SELECT AN APPROPRIATE WATER SOURCE. SURFACE WATER CRITERIA LIST A NUMBER OF SUBSTANCES THAT ARE NOT COMMONLY FOUND IN NATURE BUT ORIGINATE FROM INDUSTRIAL, AGRICULTURAL, AND DOMESTIC POLLUTION; THE CRITERIA STATE THE HIGHEST ALLOWABLE AMOUNTS OF THESE SUBSTANCES (PERMISSIVE CRITERIA) IN A WATER SOURCE AS WELL AS THE DESIRED AMOUNT ON THE BASIS OF ANTICIPATED WATER USE.

RAW SURFACE WATER CRITERIA SIMPLY SET THE LIMITS OF CONTAMINATION IN WATER PRIOR TO TREATMENT BASED ON TECHNOLOGY. STANDARDS ARE ACCEPTANCE LIMITS ON IMPURITIES THAT ARE FOUND IN WATER AFTER TREATMENT HAS OCCURRED; THESE LIMITS ARE DESIGNED TO PROTECT HUMAN HEALTH. AS WITH CRITERIA, STANDARDS VARY WITH USE (TABLES IV - X) AND MAY CHANGE APPRECIABLY WITH TIME AND/OR TECHNOLOGICAL ADVANCES (FIGURE 2).

TABLE V. SUMMARY OF SPECIFIC QUALITY CHARACTERISTICS OF SURFACE WATERS THAT HAVE BEEN USED AS SOURCES FOR PETROLEUM WATER SUPPLIES (EPA, 1973).

CHARACTERISTIC	CONCENTRATION MG/L
SILICA (SiO_2)	85
IRON (FE)	15
CALCIUM (CA)	220
MAGNESIUM (MG)	85
SODIUM AND POTASSIUM (NA AND K)	230
AMMONIA (NH_3)	40
BICARBONATE (HCO_3)	400
SULFATE (SO_4)	900
CHLORIDE (CI)	1600
FLUORIDE (F)	1.2
NITRATE (NO_3)	8
DISSOLVED SOLIDS	3500
SUSPENDED SOLIDS	5000
HARDNESS ($CaCO_3$)	900
ALKALINITY ($CaCO_3$)	500
PH, UNITS	6.0 - 9.0
COLOR, UNITS	25
CHEMICAL OXYGEN DEMAND (O_2)	1000
HYDROGEN SULFIDE (H_2S)	20

Table VI. Summary of TAPPI Specifications for Chemical Composition of Process Water for Manufacture (Technical Association of the Pulp and Paper Industry, 1957).

Substance-max ppm	Fine Paper	Kraft Paper Bleached	Kraft Paper Unbleached	Groundwood Papers	Soda and sulfite pulp
Turbidity (SiO_2)...........	10	40	100	50	25
Color in platinum units....	5	25	100	30	5
Total Hardness ($CaCO_3$).....	100	100	200	200	100
Calcuim Hardness ($CaCO_3$)...	50	-----	-----	-----	50
Alkalinity to M.O. ($CaCO_3$).	75	75	150	150	75
Iron (Fe).................	0.1	0.2	1.0	0.3	0.1
Manganese (Mn)............	0.03	0.1	0.5	0.1	0.05
Residual chlorine (Cl_2)....	2.0	-----	-----	-----	-----
Silica (soluble) (SiO_2)....	20	50	100	50	20
Total Dissolved solids.....	200	300	500	500	250
Free carbon dioxide (CO_2)..	10	10	10	10	10
Chlorides (Cl)......................		200	200	75	75
Magnesium Hardness ($CaCO_3$).........		-----	-----	-----	50

Table VII. Raw Surface Water Criteria and Drinking Water Standards for Public Water Supplies (FWPCA, 1968).

Substance		Surface Water Criteria*		Drinking Water Standards*	
		Permissive Criteria	Desirable Criteria	Preferable Limit	Rejection Limit
Coliforms	MPN	10,000	100		1
Fecal coliforms	MPN	2,000	20		1
Inorganic chemicals, mg/l					
Ammonia-N		0.5	0.01		
Arsenic		0.05	Absent	0.01	0.05
Barium		1.0	Absent		1.0
Boron		1.0	Absent		0.01
Cadmium		0.01	Absent		0.01
Chloride		250	250	250	
Chromium (hexavalent)		0.05	Absent		0.05
			Virtually		

Copper	1.0	absent	1.0	
Dissolved oxygen	4	Near Saturation		
Iron	0.3	Virtually absent	0.3	
Lead	0.05	Absent		0.05
Manganese	0.05	Absent	0.05	
Nitrate -N	10	Virtually absent	10	
Selenium	0.01	Absent		0.01
Silver	0.05	Absent		0.05
Sulfate	250	50	250	
Total dissolved solids	500	200	500	
Urany ion	5	Absent	5	
Zinc	5	Virtually absent	5	
Organic chemicals, mg/l				
ABS			0.5	
Carbon chloroform extract	0.15	0.04	0.2	
Cyanide	0.20	Absent	0.01	0.2
Oil and gases		Virtually absent		
Pesticides				
Adrian	0.017	Absent		
Chlordane	0.003	Absent		
DDT	0.042	Absent		
Dieldrin	0.017	Absent		
Endrin	0.001	Absent		
Heptachlor	0.018	Absent		
Lindane	0.056	Absent		
Methoxychlor	0.035	Absent		
Toxaphene	0.005	Absent		
Herbicides, 2,4-D +2,4,5-T + 2,4,5-TP	0.1	Absent		
Phenols	0.001	Absent	0.001	

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*Raw Water Quality Criteria for Public Supplies, National Technical Advisory Committee Report (A report to the U.S. Secretary of the Interior, issued by the Federal Water Pollution Control Administration, April 1, 1968).

Public Health Service Drinking Water Standards (Washington, D.C.: Dept. of Health, Education and Welfare, Public Health Service, 1962).

Substances that are not significantly affected by the following treatment process: coagulation (less than about 50 mg/l alum, ferric sulfate, or copperas with alkali addition as necessary but without coagulant aids or activated carbon), sedimentation (6 hr or less), rapid sand filtration (3 gpm/sq ft or less) and disinfection with chlorine (without consideration to concentration or form of chlorine residual).

202

Table VIII. Quality Characteristics of Surface Waters That Have Been Used by the Food Canning Industry.

(Unless otherwise indicated, units are mg/l and values are maximums.)

Characteristic	Concentration mg/l
Aklalinity ($CaCO_3$)	300
pH, units	8.5
Hardness ($CaCO_3$)	310
Calcium (Ca)	120
Chlorides (Cl)	300
Sulfates (SO_4)	250
Iron (Fe)	0.4
Manganese (Mn)	0.2
Silica (SiO_2)	50
Phenols	(a)
Nitrate (NO_3)	45
Nitrite (NO_2)	(c)
Fluoride (F)	(a)
Organics: carbon chloroform extract	0.3
Chemical oxygen demand (O_2)	(b)
Odor, threshold number	(a)
Taste, threshold number	(a)
Color, units	5
Dissolved solids	550
Suspended solids	12
Coliform, count/100 ml	(a)

[a] As specified in Water Quality Recommendations for Public Water Supply in this Report

[b] Accepted as received (if meeting other limiting values); has never been a problem at concentrations encountered.

[c] Not detectable by test.

ASTM 1970[4] or Standard Methods 1971.[16]

Table IX. Quality Requirements of Water at Point of Use by the Soft Drink Industry (SIC 2086)[A]

(Unless otherwise indicated, units are mg/l and values that normally should not be exceeded. The Table indicates the quality of water prior to the addition of substances used for internal conditioning.)

Characteristic	Concentration mg/l
Alkalinity ($CaCO_3$)......................	85
pH, units..............................	(B)
Hardness ($CaCO_3$).......................	(B)
Chlorides (Cl).........................	500(C)
Sulfates (SO_4).........................	500(C)
Iron (Fe)..............................	0.3
Manganese (Mn).........................	0.05
Fluoride (F)...........................	(D)
Total dissolved solids.................	(B)
Organics, CCE..........................	0.2(E)
Coliform bacteria......................	(D)
Color, units...........................	5
Taste..................................	(E,F)
Odor...................................	(E,F)

[A] The more important parameters are listed. Although not included in the table, all Drinking Water Standards (U.S. Department of Health, Education, and Welfare, Public Health Service 1962)[20] for potability apply

[B] Controlled by treatment for other constituents.

[C] If present with equivalent quantities of Mg and Ca as sulfates and chlorides, the permissible limit may be somewhat below 500mg/l.

[D] Not greater than PHS Drinking Water Standards (1962)[20].

[E] In general, public water supplies are coagulated, chlorinated, and filtered through sand and granular activated carbon to insure very low organic content and freedom from taste and odor.

[F] Not detectable by test.
ASTM 1970[4] or Standard Methods 1971[16].

TABLE X. QUALITY REQUIREMENTS OF WATER AT POINT OF USE FOR THE IRON AND STEEL INDUSTRY (SIC 33).

(UNLESS OTHERWISE INDICATED, UNITS ARE MG/L AND VALUES THAT NORMALLY SHOULD NOT BE EXCEEDED. TABLE INDICATES QUALITY OF THE WATER PRIOR TO THE ADDITION OF SUBSTANCES USED FOR INTERNAL CONDITIONING.)

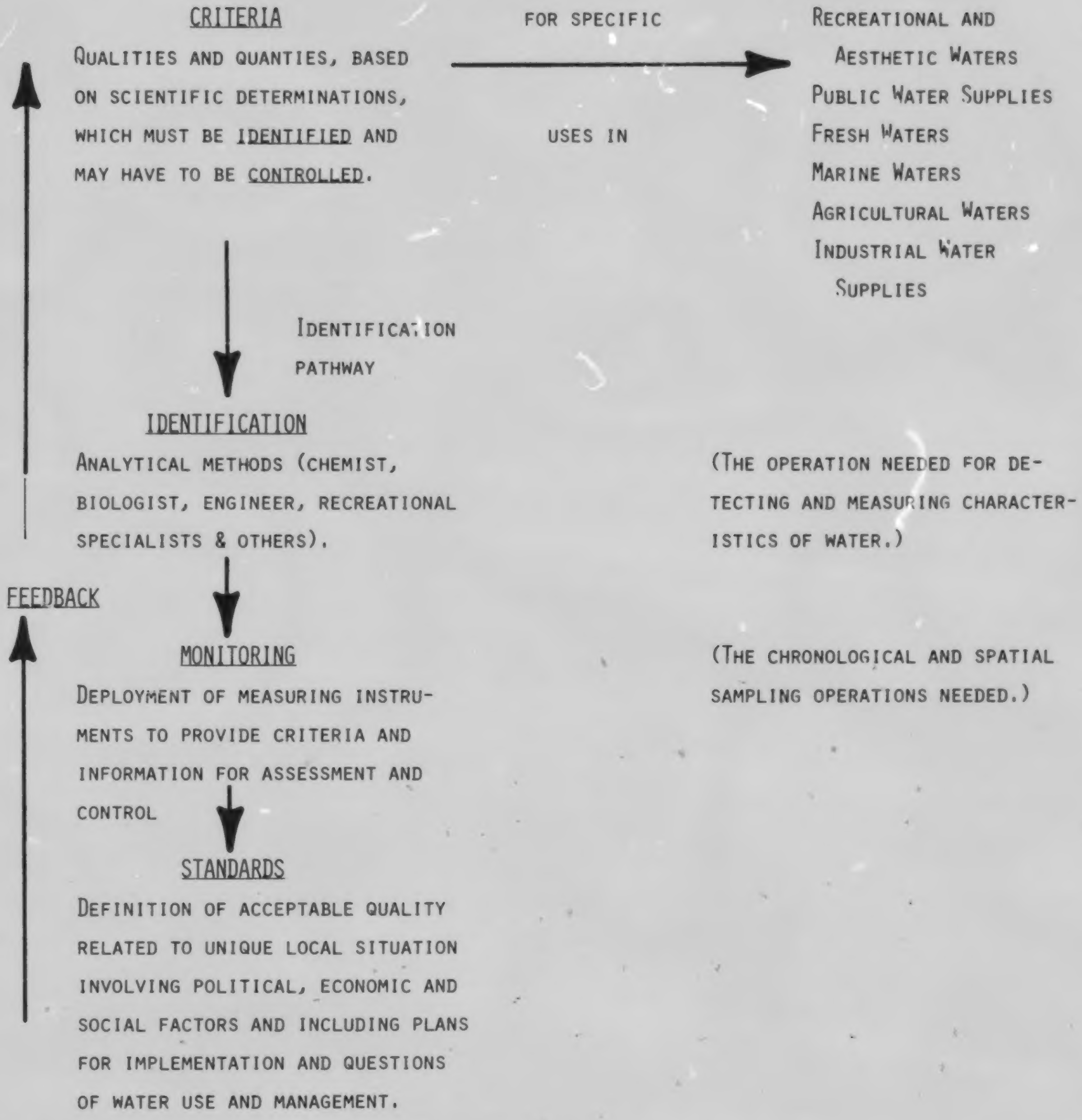
CHARACTERISTIC	QUENCHING, HOT ROLLING, GAS CLEANING	COLD ROLLING	SELECTED RINSE WATERS	
			PARTIALLY SOFTENED	DEMINERALIZED
SETTLEABLE SOLIDS.....	100	5.0	5.0	0.1
SUSPENDED SOLIDS......	(A)	10	5.0	0.1
DISSOLVED SOLIDS......	(A)	(A)	(A)	0.5
ALKALINITY ($CaCO_3$)....	(B)	(B)	(B)	0.5
HARDNESS ($CaCO_3$)......	(B)	(B)	100	0.1
pH, UNITS.............	5-9	5-9	6-9	(D)
CHLORIDE (Cl).........	(A)	(A)	(A)	0.1
DISSOLVED OXYGEN(O_2)..	(C)	(C)	(C)	(C)
TEMPERATURE, F........	100	100	100	100
OIL...................	(A)	1.0	1.0	0.02

[A] ACCEPTED AS RECEIVED IF MEETING OTHER LIMITING VALUES: HAS NEVER BEEN A PROBLEM AT CONCENTRATIONS ENCOUNTERED.

[B] CONTROLLED BY TREATMENT FOR OTHER CONSTITUENTS.

[C] MINIMUM TO MAINTAIN AEROBIC CONDITIONS.

[D] CONCENTRATION NOT KNOWN.
ASTM 1970[4] OR STANDARD METHODS 1971[16].



CRITERIA

QUALITIES AND QUANTIES, BASED ON SCIENTIFIC DETERMINATIONS, WHICH MUST BE IDENTIFIED AND MAY HAVE TO BE CONTROLLED.

RECREATIONAL AND AESTHETIC WATERS
PUBLIC WATER SUPPLIES
FRESH WATERS
MARINE WATERS
AGRICULTURAL WATERS
INDUSTRIAL WATER SUPPLIES

IDENTIFICATION

ANALYTICAL METHODS (CHEMIST, BIOLOGIST, ENGINEER, RECREATIONAL SPECIALISTS & OTHERS).

(THE OPERATION NEEDED FOR DETECTING AND MEASURING CHARACTERISTICS OF WATER.)

MONITORING

DEPLOYMENT OF MEASURING INSTRUMENTS TO PROVIDE CRITERIA AND INFORMATION FOR ASSESSMENT AND CONTROL

(THE CHRONOLOGICAL AND SPATIAL SAMPLING OPERATIONS NEEDED.)

STANDARDS

DEFINITION OF ACCEPTABLE QUALITY RELATED TO UNIQUE LOCAL SITUATION INVOLVING POLITICAL, ECONOMIC AND SOCIAL FACTORS AND INCLUDING PLANS FOR IMPLEMENTATION AND QUESTIONS OF WATER USE AND MANAGEMENT.

FIGURE 2. CONCEPTUAL FRAMEWORK FOR DEVELOPING STANDARDS FROM CRITERIA (EPA, 1973).

ALL INTERSTATE BODIES OF WATER IN THE UNITED STATES ARE DESCRIBED AND CLASSIFIED ON THE BASIS OF THE FOLLOWING SYSTEM (NEW ENGLAND INTERSTATE WATER POLLUTION CONTROL COMMISSION, 1969):

GENERAL POLICY, CLASSIFICATION AND STANDARDS OF QUALITY FOR INTERSTATE WATERS - STANDARDS

Water use class and description	Dissolved oxygen	Sludge deposits, solid refuse floating solids, oil, grease, and scum	Color and Turbidity
		Inland Waters	
A - suitable for water supply with treatment by disinfection only, and all other water uses; character uniformly excellent	As naturally occurs	None other than of natural origin	None other than of natural origin
B - suitable for bathing and other primary contact recreation. Acceptable for public water supply with appropriate treatment.[c] Suitable for agricultural and certain industrial process and cooling uses. Suitable as an excellent fish and wildlife habitat. Excellent aesthetic value	Minimum 5 mg/l at any time. Normal seasonal and diurnal variations above 5 mg/l will be maintained	None allowable	None in such concentrations that would impair any usages specifically assigned to this class
C - suitable for fish and wildlife habitat, boating, fishing, and certain industrial process and cooling uses. Under some conditions acceptable for public water supply with appropriate treatment. Good aesthetic value[c]	Minimum 5 mg/l any time. Normal seasonal and diurnal variations above 5 mg/l will be maintained. For sluggish eutrophic waters, not less than 3 mg/l at any time. Normal seasonal and diurnal variations above 3 mg/l will be maintained	None[b]	None in such concentrations that would impair any usages specifically assigned to this class
D - suitable for navigation, power, certain industrial processes and cooling uses, and migration of fish. Aesthetically acceptable	2 mg/l at any time. Normal seasonal and diurnal variations above 2 mg/l will be maintained	None[b]	None in such concentrations that would impair any usages specifically assigned to this class

Coliform bacteria	Taste and odor	pH	Allowable temperature increase
	Inland Waters		
Total coliforms: not to exceed a monthly arithmetic mean of 100/100 ml[d]	None other than of natural origin	As naturally occurs	None other than of natural origin
Total coliforms: Not to exceed a monthly median of 1,000/100 ml nor more than 2,400/100 ml in more than 20% of samples collected[d]	None in such concentrations that would impair any usages specifically assigned to this class nor cause taste and odor in edible fish	6.5 - 8.0	Only such increases that will not impair any usages specifically assigned to this class
d	None in such concentrations that would impair any usages specifically assigned to this class nor cause taste and odor in fish	6.0 - 8.5	Only such increases that will not impair any usages specifically assigned to this class[e]
None in such concentrations that would impair any usages specifically assigned to this class	None in such concentrations that would impair any usages specifically assigned to this class	6.0 - 9.0	Only such increases that will not impair any usages specifically assigned to this class[e]

Coastal and Marine Waters[f,h,i2]

SA - suitable for all sea water uses including shellfish harvesting for direct human consumption (approved shellfish areas), bathing, and other sports; excellent aesthetic value	Not less than 5.0 mg/l at any time. Normal seasonal and diurnal variations above 5 mg/l will be maintained	None allowable	None in such concentrations that would impair any usages specifically assigned to this class
SB - suitable for bathing, other recreational purposes, industrial cooling and shellfish harvesting for human consumption after depuration, excellent fish and wildlife habitat, good aesthetic value	Not less than 5.0 mg/l at any time. Normal seasonal and diurnal variations above 5 mg/l will be maintained	None allowable	None in such concentrations that would impair any usages specifically assigned to this class
SC - suitable fish, shellfish and wildlife habitat; suitable for recreational boating, and industrial cooling; good aesthetic value	A minimum of 2 mg/l at any time. Normal seasonal and diurnal variations above 2 mg/l will be maintained	None except for such small amounts that may result from the discharge of appropriately treated sewage and/or industrial waste effluents	None in such concentrations that would impair any usages specifically assigned to this class
SD - suitable for navigation, power, certain industrial processes and cooling uses, and migration of fish; good aesthetic value	Not less than 5 mg/l during daylight hours nor less than 4 mg/l at any time. Normal seasonal and diurnal variations above 4 mg/l will be maintained	None except that the amount that may result from the discharge from a waste treatment facility providing appropriate treatment	None in such concentrations that would impair any usages specifically assigned to this class

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[a] Class A waters reserved for water supply may be subject to restricted use by state and local regulation.

[b] Sludge deposits, floating solids, oil, grease, and scum shall not be allowed except in that amount that may result from the discharge of appropriately designed and operated sewage and/or industrial waste treatment plants.

[c] Waters shall be free from chemical and radiological constituents in concentrations or combinations which would be harmful to human, animal, or aquatic life for the most sensitive and governing water class use. In areas where fisheries are the governing considerations and approved limits have not been established, bioassays shall be performed as required by the appropriate agencies. For public drinking water supplies the raw water sources must be of such a quality that United States Public Health Service or higher appropriate state agency limits for finished water can be met after conventional water treatment.

[d] Water quality analyses on interstate waters should include tests for both total and fecal coliform supported by sanitary surveys in the development of background data and the establishment of baselines for these two parameters for the specific waters involved.

[e] The resultant temperature of a receiving water shall not exceed that shown for the most sensitive aspect of the most sensitive specie of aquatic life in that water. Normal seasonal and diurnal temperature variations that existed before the addition of heat of artificial origin shall be maintained. In addition:

1. for streams, the allowable total temperature rise shall not exceed 5° F above ambient unless it can be demonstrated to the satisfaction of the state regulatory agencies that greater rises at various times will not be harmful to fish, other aquatic life or other uses.
2. for lakes, there shall be no discharge or withdrawal of cooling waters from the hypolimnion unless it can be demonstrated to the satisfaction of the state regulatory agencies that such discharges or withdrawals will not be harmful to fish, other aquatic life or other uses. A heated discharge to a lake shall not raise the temperature more than 3° F at the surface immediately outside a designated mixing zone.

More restrictive requirements may be adopted by a state if deemed necessary to meet the class use of the receiving waters.

Source: New England Interstate Water Pollution Control Commission, Standards of Water Quality, 1969.

Coastal and Marine Waters[f,h,i][2]

SA - suitable for all sea water use including shellfish harvesting for direct human consumption (approved shellfish areas), bathing, and other water contact sports; excellent aesthetic value	Not to exceed a median MPN of 70/100 ml and not more than 10% of the samples shall ordinarily exceed an MPN of 230/100 ml for a 5-tube decimal dilution or 330/100 ml for a 3-tube decimal dilution[g]	None allowable	6.8 - 8.5
SB - suitable for bathing, other recreational purposes, industrial cooling and shellfish harvesting for human consumption after depuration; excellent fish and wildlife habitat, good aesthetic value	Not to exceed a median of 700/100 ml and not more than 2,300/100 ml in more than 10% of the samples collected in a 30 day period[g]	None in such concentrations that would impair any usages specifically assigned to this class and none that would cause taste and odor in edible fish or shellfish	6.8 - 8.5
SC - suitable fish, shellfish, and wildlife habitat; suitable for recreational boating, and industrial cooling; good aesthetic value	g	None in such concentrations that would impair any usages specifically assigned to this class and none that would cause taste and odor in edible fish or shellfish	6.0 - 9.0
SD - suitable for navigation, power, certain industrial processes and cooling uses, and migration of fish; good aesthetic value	None in such concentrations that would impair any usages specifically assigned to this class	None in such concentrations that would impair any usages specifically assigned to this class and none that would cause taste and odor in edible fish or shellfish	6.8 - 8.5

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[f] Coastal and marine waters are those generally subject to the rise and fall of the tide.

[g] Surveys to determine coliform concentrations shall include those areas most probably exposed to fecal contamination during the most unfavorable hydrographic and pollution conditions. Water quality analyses on interstate marine and coastal waters should include tests for both total and fecal coliform supported by sanitary surveys for development of background data and the establishment of a baseline for these two parameters for the specific waters involved.

[h] Waters shall be free from chemical and radiological concentrations or combinations which would be harmful to human, animal, or aquatic life or which would make the waters unsafe or unsuitable for fish or shellfish or their propencity to impair the palatability of same, or impair the water for any other usage. In areas where fisheries are the governor, considerations and approved limits have not been established, bioassays shall be performed as required by the appropriate agencies.

[i] The temperature of a receiving water shall not exceed that shown below immediately outside a designated mixing zone:

1. Coastal Waters
   The water temperature at the surface of coastal waters shall not be raised more than 4° F over the monthly means of maximum daily temperatures from October through June nor more than 1.5° F from July through September.
2. Estuaries or portions of estuaries
   The water temperature at the surface of an estuary shall not be raised to more than 90 F at any point provided further, at least 50 percent of the cross sectional area and/or volume of the flow of the estuary including a minimum of 1/3 of the surface as measured from water edge to water edge at any stage of tide shall not be raised to more than 4° F over the temperature that existed before the addition of heat of artificial origin or a maximum of 83° F, whichever is less. However, during July through September if the water temperature at the surface of an estuary before the addition of heat of artificial origin is more than 83° F, an increase in temperature not to exceed 1.5° F, at any point of the estuarine passageway as delineated above, may be permitted.
   More restrictive requirements may be adopted by a state if deemed necessary for the protection of the most sensitive aspect of the most sensitive specie of aquatic life in that water and/or to meet the class use of the receiving water.

WATER TREATMENT

TO MEET THE STANDARDS PROSCRIBED FOR VARIOUS BODIES OF WATER, RELATIVELY STANDARD TREATMENT PROCESSES HAVE BEEN EMPLOYED. THE STEPS ARE AS FOLLOWS:

COAGULATION--a chemical process involving the addition of aluminum sulfate and ferric chloride, coagulant acids (polyelectrolytes), acids, alkalis, and/or clays to induce gathering of light or finely divided particles for removal.

SEDIMENTATION--a physical process, as with wastewater treatment, in which large or heavy particles are removed by gravity (settling).

FILTRATION--filtration is a process used for further clarification by passing water through sand, anthracite, diatomite, or carbon mediums to remove fine materials. Under carefully controlled conditions, these stages of treatment can reduce bacterial and viral counts greatly. According to the National Research Council (1977), careful sedimentation and filtration can actually reduce viral content from 90-99%.

DISINFECTION--used for the specific control of bacteria. Viruses, although more resistant to this process than bacteria, can also be reduced. Chlorine or chlorine compounds (such as chloride of lime or sodium hypochlorite) are generally used because of low cost, dependability, efficiency, and ease of handling.

HISTORICALLY, THESE TREATMENT PROCESSES PLACED A MAJOR EMPHASIS ON THE DETECTION AND DISINFECTION OF MICROBIAL CONTAMINANTS AND A SECONDARY EMPHASIS ON GROSS HARDNESS, WATER CLARITY, COLOR, TASTE, AND ODOR. IN RECENT YEARS, QUESTIONS HAVE BEEN RAISED AS TO THE ADEQUACY OF THE TREATMENT STEPS. OF PRIMARY CONCERN IS THE ABILITY OF CONVENTIONAL STEPS TO REMOVE NEW CONTAMINANTS SUCH AS PESTICIDES, HERBICIDES, AND MANY OTHER BY-PRODUCTS OF A HIGHLY INDUSTRIALIZED SOCIETY. A SECOND CONCERN STEMS FROM THE UTILIZATION OF EXCESSIVE AMOUNTS OF CHLORINE IN THE DISINFECTION STAGE SINCE CHLORINE HAS BEEN SHOWN TO BE CARCINOGENIC TO LABORATORY ANIMALS IN HIGH AMOUNTS. THIRDLY, QUESTIONS HAVE BEEN RAISED CONCERNING THE ADEQUACY OF SAMPLING RATES AND PROCEDURES AND THE USE OF "INDICATOR ORGANISMS".

WASTEWATER TREATMENT PROCESSES AND ALTERNATIVES

IN GENERAL, DOMESTIC SEWAGE TREATMENT HAS TO WORRY ABOUT BIOLOGICAL OXYGEN DEMAND (BOD), TOTAL SUSPENDED SOLIDS, FECAL COLIFORM BACTERIA, PHOSPHORUS, AND NITROGEN (NITRATES, NITRATES AND AMMONIA) REMOVAL. IF MUNICIPAL TREATMENT FACILITIES RECEIVE WASTES FROM INDUSTRIES, THEY WILL BE CONFRONTED WITH A WIDE RANGE OF POLLUTANTS. INDUSTRIAL PLANTS, UNLESS THEY OPERATE THEIR OWN SANITARY TREATMENT PLANTS, ARE GENERALLY LESS CONCERNED WITH BOD AND FECAL COLIFORM BACTERIA AND MORE CONCERNED WITH TOXIC SUBSTANCES, HEAT, AND INORGANIC CHEMICALS AND MINERAL SUBSTANCES.

THE BASIC POLLUTANTS OF CONCERN, WHETHER A PRIVATE, PUBLIC, OR INDUSTRIAL TREATMENT FACILITY, CAN BE SEPARATED INTO EIGHT GENERAL CATEGORIES (EPA, 1973):

OXYGEN-DEMANDING WASTES-- These are the traditional organic wastes and ammonia contributed by domestic sewage and industrial wastes of plant and animal origin. Besides human sewage, such wastes result from food processing, paper mill production, tanning and other manufacturing processes. These wastes are usually destroyed by bacteria if there is sufficient oxygen present in the water. Since fish and other aquatic life depend on oxygen for life, the oxygen-demanding wastes must be controlled, or the fish die.

BACTERIA AND VIRUSES-- This category includes infectious organisms which are carried into surface and ground water by sewage from cities and institutions, and by certain kinds of industrial wastes, such as tanning and meak packaging plants. As early as 1854, it was established that cholera was transmitted by sewage-contaminated drinking water. A hepatitis epidemic in Delhi, India in 1955 was also traced to contamination of a water supply by sewage. An ameobic dysentery outbreak in Chicago in 1933 from sewage-contaminated water caused 23 deaths. Man or animals come in contact with these microbes either by drinking the water or through swimming, fishing, or other activities. Although modern disinfection techniques have greatly reduced the danger of this type of pollutant, the problem must be watched constantly.

PLANT NUTRIENTS-- These are the substances in the food chain of aquatic life, such as algae and water weeds, which support and stimulate their growth. Carbon, nitrogen and phosphorus are the three chief nutrients present in natural water. Large amounts of these nutrients are produced by sewage, certain industrial wastes, and drainage from fertilized lands. Biological waste treatment processes do not remove the phosphorus and nitrogen to any substantial extent--in fact, they convert the organic forms of these substances into mineral form, making them more usable by plant life. The problem starts when an excess of these nutrients over-stimulates the growth of water plants which cause unsightly conditions, interfere with treatment processes, and cause unpleasant and disagreeable tastes and odors in the water.

SYNTHETIC ORGANIC CHEMICALS-- Included in this category are detergents and other household aids, all the new synthetic organic pesticides, synthetic industrial chemicals, and the wastes from their manufacture. Many of these substances are toxic to fish and aquatic life and possibly harmful to humans. They cause taste and odor problems and resist conventional waste treatment. Some are known to be highly poisonous at very low concentrations. What the long-term effects of small doses of toxic substances may be is not yet known.

INORGANIC CHEMICALS AND MINERAL SUBSTANCES-- A vast array of metal salts, acids, solid matter, and many other chemical compounds are included in this group. They reach our waters from mining and manufacturing processes, oil field operations, agricultural practices, and natural sources. Water used irrigation picks up large amounts of minerals as it filters down through the soil on its way to the nearest stream. Acids of wide variety are discharged as wastes by industry, but the largest single source of acid in our water comes from mining operations and mines that have been abandoned. Many of these types of chemicals are being created each year. They interfere with natural stream purification; destroy fish and other aquatic life; cause excessive hardness of water supplies; corrode expensive water treatment equipment; increase commercial and recreational boat maitenance costs; and boost the cost of waste treatment.

SEDIMENTS-- These are the particles of soils, sands, and minerals washed from the land and paved areas of communities into the water. Construction projects are often large sediment producers. While not as insidious as some other types of pollution, sediments are a major problem because of the sheer magnitude of the amount reaching our waterways. Sediments fill stream channels and harbors, requiring expensive dredging, and they fill reservoirs, reducing their capacities and useful life. They erode power turbines and pumping equipment, and reduce fish and shellfish populations by blanketing fish nests and food supplies. More importantly, sediments reduce the amount of sunlight penetrating the water. The sunlight is required by green aquatic plants which produce the oxygen necessary to normal stream balance. Sediments greatly increase the treatment costs for municipal and industrial water supply and for sewage treatment where combined sewers are in use.

RADIOACTIVE SUBSTANCES-- Radioactive pollution results from the mining and processing of radioactive ores; from the use of refined radioactive materials in power reactors and for industrial, medical, and research purposes; and from fallout following nuclear weapons testing. Increased use of these substances poses a potential public health problem. Since radiation accumulates in humans, control of this type of pollution must take into consideration total exposure in the human environment--water, air, food, occupation, and medical treatment.

HEAT-- Heat reduces the capacity of water to absorb oxygen. Tremendous volumes of water are used by power plants and industry for cooling. Most of the water, with the added heat, is returned to streams, raising their temperatures. With less oxygen, the water is not as efficient in assimilating oxygen-consuming wastes and in supporting fish and aquatic life. Unchecked waste heat discharges can seriously alter the ecology of a lake, a stream, or even part of the sea. Water in lakes or stored in impoundments can be greatly affected by heat. Summer temperatures heat up the surfaces, causing the water to form into layers, with the cooler water forming the deeper layers. Decomposing vegetative matter from natural and man-made pollutants deplete the oxygen from these cooler lower layers with harmful effects on the aquatic life. When the oxygen-deficient water is discharged from the lower gates of a dam, it may have serious effects on downstream fish life and reduce the ability of the stream to assimilate downstream pollution.

TO COMPLICATE MATTERS, MOST OF OUR WASTES ARE A MIXTURE OF THE EIGHT TYPES OF POLLUTION AND IN THE CASE OF MUNICIPAL WASTEWATER, ARE FOUND IN VERY DILUTE CONCENTRATIONS. MUNICIPAL WASTEWATER IS USUALLY 99.94 PERCENT WATER; THUS THE CONCENTRATIONS OF THE POLLUTANTS DISCUSSED ARE VERY SMALL--USUALLY EXPRESSED AS MILLIGRAMS OF POLLUTANT PER LITER OF WATER (MG/L). ONE MG/L OF A POLLUTANT IS EQUIVALENT TO 1 PART OF THE POLLUTANT (BY WEIGHT) IN 1 MILLION PARTS OF WATER--OR, AS EXPRESSED IN ANOTHER OFTEN-USED TERM, 1 PART PER MILLION (PPM). ONE MG/L OR 1 PPM, TO PUT THE TERMS IN PERSPECTIVE, IS EQUIVALENT TO 1 MINUTE OF TIME IN 1.9 YEARS OR 1 INCH IN 16 MILES. THESE STATISTICS EMPHASIZE THAT WASTEWATER TREATMENT PROCESSES DESIGNED TO REMOVE A FEW MILLIGRAMS PER LITER OF A POLLUTANT ARE SIMILAR TO SIFTING A HAYSTACK TO REMOVE THE NEEDLE. HOWEVER, THE BALANCE IN NATURE FOR SURVIVAL OR DEATH OF FISH DEPENDS ON THE PRESENCE OR ABSENCE OF ONLY 2-3 MG/L OF OXYGEN IN THE STREAM OR LAKE, AND UNDESIRABLE GROWTHS OF ALGAE CAN BE STIMULATED BY A FEW TENTHS OF A MILLIGRAM OF PHOSPHORUS AND NITROGEN PER LITER. TYPICAL CONCENTRATIONS OF POLLUTANTS IN RAW, UNTREATED, MUNICIPAL WASTEWATERS ARE AS FOLLOWS: BOD = 150-250 MG/L, COD = 300-400 MG/L, SUSPENDED SOLIDS = 150-250 MG/L, NITROGEN = 15-25 MG/L, AND TOTAL DISSOLVED SUBSTANCES = 400-500 MG/L.

ALTERNATIVES FOR WASTEWATER MANAGEMENT

CONCERN OVER THE REMOVAL OF DOMESTIC WASTEWATER IS NOT A NEW PHENOMENA. ANCIENT TOWNS IN PERSIA WERE KNOWN TO HAVE BATH AND KITCHEN DRAINAGE SYSTEMS AS EARLY AS 2500 B.C. (GRAY, 1940). UNFORTUNATELY, MOST OF THE EARLY WASTEWATER REMOVAL SYSTEMS SIMPLY DISPLACED THE WASTE MATERIALS FROM THE INTERIOR OF HOUSEHOLDS TO PUBLIC THOROUGHFARES LIKE STREETS AND WALKS. ACTUAL TREATMENT OF WASTES WERE LEFT TO CHANCE AND DEPENDED ON CLIMATIC AND BIOLOGICAL FACTORS LIKE PRECIPITATION, BACTERIAL DECOMPOSITION, AND ANIMAL SCAVENGING TO DISPOSE OF THE WASTES.

TODAY, DOMESTIC, COMMERCIAL AND INDUSTRIAL WASTEWATER TREATMENT SYSTEMS FALL INTO TWO GENERAL CATEGORIES--I.E., THOSE THAT ARE SERVICED BY SEWERS AND THOSE THAT ARE NOT. SEWERED SYSTEMS ARE COMMONLY FOUND IN METROPOLITAN AND INDUSTRIAL AREAS WHERE THE BENEFITS OF A CENTRAL TREATMENT FACILITY OUTWEIGH THE COST OF SEWER INSTALLATION. WASTEWATER TREATMENT SYSTEMS MAY INVOLVE RELATIVELY SOPHISTICATED FACILITIES AND PROCEDURES OR THE SYSTEMS MAY BE RELATIVELY SIMPLISTIC, DEPENDING ON THE COMPOSITION AND AMOUNTS OF EFFLUENTS RECEIVED. UNSEWERED SYSTEMS TYPICALLY INCLUDE ON-SITE DISPOSAL SYSTEMS, LIKE SEPTIC OR HOLDING TANKS; THESE SYSTEMS GENERALLY SERVICE RURAL OR SUBURBAN AREAS WHERE POPULATION DENSITIES ARE TOO LOW TO JUSTIFY THE INSTALLATION COSTS OF A CENTRAL TREATMENT FACILITY AND LINES.

SINCE WASTEWATER IS BASICALLY "USED" WATER THAT MAY COME FROM A HOUSEHOLD, AN INDUSTRY, A COMMERCIAL ENTERPRISE, OR EVEN STORM AND GROUND WATER, IT HAS AN EXTREMELY VARIED COMPOSITION. TECHNICIANS LIKE TO DIVIDE DOMESTIC AND COMMERCIAL WASTEWATER INTO TWO CATEGORIES: BLACK WATER (TOILET WASTES) AND GRAY WATER (KITCHEN, CLEANING, AND LAUNDRY WASTEWATER). INDUSTRIAL WASTEWATERS, ON THE OTHER HAND, MAY CONSIST OF LARGE VOLUMES OF WATER USED IN PROCESSING INDUSTRIAL PRODUCTS, WHICH GENERALLY CONTAIN HIGHER CONCENTRATIONS OF THE EIGHT POLLUTANTS PREVIOUSLY MENTIONED DUE TO WATER RECYCLING IN THE PLANT AND THE PROCESSES INVOLVED. WATER THAT DRAINS OFF THE LAND VIA STORM SEWERS CONTAINS GREAT AMOUNTS OF ORGANIC MATTER AND SEDIMENT. LAND DRAINAGE MAY ALSO CONTAIN RADIOACTIVE SUBSTANCES AND POLLUTANTS WASHED FROM THE SKY, VEGETATION, BUILDINGS, AND STREETS DURING A RAINFALL.

WHATEVER THE SOURCE--AND THUS COMPOSITION OF THE WASTEWATER, TREATMENT FACILITIES MUST BE CAPABLE OF DISPOSING OF THE WASTES IN SUCH A MANNER AS TO PREVENT ENVIRONMENTAL CONTAMINATION AND STILL PROVIDE THE SERVICE AT REASONABLY LOW ECONOMIC COSTS.

SEWERED WASTEWATER TREATMENT SYSTEMS

IN METROPOLITAN AREAS, WASTEWATER COMES FROM FIVE MAJOR SOURCES: COMMERCIAL, INDUSTRIAL, RESIDENTIAL, STORM SEWERS, AND GROUNDWATER. TO HANDLE THE LARGE VOLUMES OF WASTEWATER PRODUCED, SEWAGE PLANTS ARE GENERALLY DESIGNED AND CONSTRUCTED TO TREAT ANTICIPATED SOURCES AND VOLUMES OF WASTEWATERS. DEPENDING ON THE CHANGES OCCURRING IN A MUNICIPALITY

IN TERMS OF INDUSTRIAL, COMMERCIAL, AND RESIDENTIAL GROWTH, AS WELL AS CHANGES IN WATER STANDARDS FOR EFFLUENTS, A TREATMENT PLANT CAN BECOME OUTMODED EARLIER THAN EXPECTED. SHORTENING THE LIFE EXPECTANCY OF A TREATMENT PLANT IS A VERY COSTLY EXPERIENCE TO TAXPAYERS WHO GENERALLY ARE NOT CONCERNED WITH WASTE DISPOSAL UNTIL IT AFFECTS THEIR POCKETBOOKS. ON THE OTHER HAND, MUNICIPALITIES DO NOT WANT TO BUILD FACILITIES THAT ARE TOO LARGE OR TOO SOPHISTICATED FOR THE AMOUNT AND NATURE OF WASTEWATERS PRODUCED IN THEIR AREA. THIS TOO IS AN ECONOMIC BURDEN FOR TAXPAYERS AND AN INEFFICIENT USE OF LAND, ENERGY, AND PERSONNEL. SO A COMPROMISE IS STRUCK; MOST PLANTS ARE BUILT USING THE "BEST PRACTICABLE TECHNOLOGY" (BPT) AT THE TIME WITH AN EYE TO MORE STRINGENT EFFLUENT GUIDELINES THAT MAY BE FORTHCOMING, GENERALLY TERMED "BEST AVAILABLE TECHNOLOGY" (BAT). BY ANTICIPATING (1) A COMMUNITY'S GROWTH WHICH MAY INCLUDE NEW INDUSTRIAL "HOOK-UPS" WITH A MUNICIPAL PLANT, NEW SEWAGE AND STORM-WATER LINES IN EXPANDING RESIDENTIAL AREAS, AND ADDITIONAL COMMERCIAL BUILDINGS, AND (2) CHANGES IN EFFLUENT STANDARDS AND AVAILABLE TECHNOLOGY, MUNICIPALITIES CAN HAVE ADEQUATE TREATMENT FACILITIES WITHOUT WASTEFUL SPENDING OF TAX DOLLARS. (PLEASE REFER TO THE SECTION OF THE CURRICULUM ENTITLED INDUSTRY'S STAKE IN CLEAN WATER FOR MORE INFORMATION ON EFFLUENT STANDARDS).

TREATMENT PROCESSES

WHETHER A TREATMENT PLANT IS HANDLING INDUSTRIAL WASTES OR MUNICIPAL WASTES, THE TREATMENT PROCESSES ARE GENERALLY THE SAME AND ARE USUALLY DIVIDED INTO THE FOLLOWING STAGES: PRETREATMENT, PRIMARY TREATMENT, SECONDARY TREATMENT, TERTIARY TREATMENT, AND SLUDGE DISPOSAL. TABLE XI PROVIDES A DESCRIPTION OF EACH OF THESE PROCESSES AND THEIR ADVANTAGES, LIMITATIONS, AND APPLICATIONS. FOR THE PURPOSE OF UNDERSTANDING THE PROCESSES BETTER, WE WILL BRIEFLY DESCRIBE THE GENERAL GOAL OF EACH STAGE OF TREATMENT AND SOME OF THE MORE COMMON TREATMENT STRATEGIES. (TABLE XI BEGINS ON PAGE 224.)

PRETREATMENT--PRETREATMENT INVOLVES THE "CONDITIONING" OF WASTEWATER BEFORE IT BECOMES EXPOSED TO OTHER TREATMENT STAGES AT THE PLANT. IN PARTICULAR, THIS CONDITIONING IS AIMED AT PROTECTING THE BIOLOGICAL BREAKDOWN FORCES AT WORK IN THE SECONDARY TREATMENT STAGE. PRETREATMENT USUALLY INVOLVES ONE OR MORE OF THE FOLLOWING PROCESSES:

FLOW EQUALIZATION--This is a technique that is used to dampen variations in the amounts and concentrations of wastewater so that it can be treated at nearly a constant flow rate. Large basins are used to collect and store the wastewater which is then pumped to the treatment plant at a constant rate. Because of the low cost involved in providing flow equalization, many treatment plants now include it in their design since it can significantly improve the performance of an existing plant and increase its useful capacity by minimizing "peaks" and "troughs" in wastewater flow to a plant.

NEUTRALIZATION-- This process involves chemical recombinations with highly acidic, basic, or toxic wastes that could have a major impact on the biological and chemical processes occurring in a treatment plant. Generally, wastewaters that require neutralization are products of an industrial process where strong acids or bases are used in the manufacturing process. Depending on the pH of the wastewater, a chemical is added to bring the pH back to a neutral state (i.e., neither acid or basic).

TEMPERATURE ADJUSTMENT-- Attempts to bring water temperatures to optimum biological levels (approximately 37°C) involves the heating or cooling of wastewater entering a treatment plant. Waters that are either too hot or too cold, will produce an unfavorable environment for the bacterial decomposition of organic wastes.

NUTRIENT ADDITIONS-- Occasionally wastewaters entering a plant are high in carbon compounds but low in nitrogen and/or phosphorus. It has already been pointed out that the production of 100 pounds of new plant cells requires approximately 7 pounds of nitrogen and 1 pound of phosphorus. In the case of sewage treatment plants, plant growth is encouraged in the secondary treatment process as a means of reducing the oxygen demanding waste load on receiving bodies of water. The addition of nutrients to domestic wastewater is a rarity.

PRIMARY TREATMENT--THE MAJOR GOAL OF PRIMARY TREATMENT IS TO REMOVE FROM WASTEWATER THOSE POLLUTANTS WHICH WILL EITHER SETTLE OUT DUE TO GRAVITY OR FLOAT (SUCH AS GREASE). PRIMARY TREATMENT WILL TYPICALLY REMOVE ABOUT 60 PERCENT OF THE SUSPENDED SOLIDS AND 35 PERCENT OF THE BOD. SOLUABLE POLLUTANTS ARE NOT REMOVED. AT ONE TIME THIS WAS THE DEGREE OF TREATMENT USED BY MANY CITIES. NOW FEDERAL LAW REQUIRES THAT MUNICIPALITIES PROVIDE THE HIGHER DEGREE OF TREATMENT PROVIDED BY SECONDARY TREATMENT. ALTHOUGH PRIMARY TREATMENT ALONE IS NO LONGER ACCEPTABLE, IT IS STILL FREQUENTLY USED AS THE FIRST TREATMENT STEP IN A SECONDARY TREATMENT SYSTEM. THUS, PAST INVESTMENTS IN PRIMARY TREATMENT FACILITIES PROVIDE USEFUL TREATMENT FUNCTIONS WHEN TREATMENT IS UPGRADED TO THE SECONDARY LEVEL. PRIMARY TREATMENT CAN INVOLVE ONE OR MORE OF THE FOLLOWING PROCESSES: SCREENING, GRIT REMOVAL, SEDIMENTATION, AND/OR DISSOLVED-AIR FLOTATION.

SCREENS--screens are used to remove large floating objects, such as rags and sticks that make their way into wastewater. A typical screen is made of parallel steel or iron bars with opening of about half an inch. They are generally placed in a chamber or channel in an inclined position to the flow of the sewage (to make cleaning easier) to catch debris on the upstream side of the screen. This debris is then transported to a landfill site.

GRIT CHAMBER--a grit chamber is essentially a settling basin where sand, grit, cinders, and small stones settle to the bottom. It is an extremely important primary treatment step in cities where combined sewer systems occur because rainfall will remove the grit and gravel that exist in streets and transfer it to the local treatment plant. The material that settles out in a grit chamber is often washed and then used in landfill sites.

SEDIMENTATION BASINS-- suspended solids that still remain in the wastewater after screening and grit removal has occurred are usually exposed to sedimentation basins. Sedimentation basins are usually round or rectangular tanks that hold wastewater for periods of 2-3 hours. Wastewater flows very slowly through them. As a result, suspended solids gradually sink to the bottom and floating materials, such as grease and oil, rise to the surface. The suspended solids are removed from the tank by mechanical scraper and pumps and comprise what is known as "raw primary sludge". The oils and grease are usually removed by a skimmer system and then transferred for further digestion.

DISSOLVED-AIR FLOTATION DEVICES-- this apparatus serves the same function as sedimentation basins but requires less area than for a sedimentation tank, but more energy for operation.

SECONDARY TREATMENT--THE MAJOR GOAL OF SECONDARY TREATMENT IS TO REMOVE THE SOLUABLE BOD THAT ESCAPES THE PRIMARY PROCESS AND TO PROVIDE ADDED REMOVAL OF SUSPENDED SOLIDS. THESE REMOVALS ARE TYPICALLY ACHIEVED BY USING BIOLOGICAL PROCESSES, PROVIDING THE SAME BIOLOGICAL REACTIONS THAT WOULD OCCUR IN THE RECEIVING WATER IF IT HAD ADEQUATE CAPACITY TO ASSIMILATE THE WASTEWATER DISCHARGES. THE SECONDARY TREATMENT PROCESSES ARE DESIGNED TO SPEED UP THESE NATURAL PROCESSES SO THAT THE BREAKDOWN OF THE DEGRADABLE ORGANIC POLLUTANTS CAN BE ACHIEVED IN RELATIVELY SHORT TIME PERIODS IN TREATMENT UNITS THAT RELIEVE OUR STREAMS AND LAKES OF THE PURIFICATION BURDEN. ALTHOUGH SECONDARY TREATMENT MAY REMOVE MORE THAN 85 PERCENT OF THE BOD AND SUSPENDED SOLIDS, IT DOES NOT REMOVE SIGNIFICANT AMOUNTS OF NITROGEN, PHOSPHORUS, COD, OR HEAVY METALS, NOR DOES IT COMPLETELY REMOVE PATHOGENIC BACTERIA AND VIRUSES. THESE LATTER POLLUTANTS MAY REQUIRE FURTHER REMOVAL WHERE RECEIVING WATERS ARE ESPECIALLY SENSITIVE.

SECONDARY TREATMENT CAN INVOLVE A VARIETY OF PROCESSES AND VARIATIONS ON THESE PROCESSES DEPENDING ON THE SOPHISTICATION OF THE WASTEWATER TREATMENT FACILITY AND THE NATURE OF THE WASTEWATERS BEING TREATED. THE ENVIRONMENTAL PROTECTION AGENCY (1976) IN THEIR BOOKLET ENTITLED "ENVIRONMENTAL POLLUTION CONTROL ALTERNATIVES: MUNICIPAL WASTEWATER" DESCRIBES SOME OF THE MOST COMMON SECONDARY TREATMENT PROCESSES NOW IN USE. THE FOLLOWING IS AN EXERPT FROM THIS BOOKLET.

> TRICKLING FILTERS - A trickling filter consists of a bed of coarse material, such as stones, slats, or plastic materials, over which wastewater is applied in drops, films, or spray from moving distributors or fixed nozzles, and through which it trickles to underdrains. As the wastewater trickles through the bed, microbial growth occurs on the surface of the stone and consumes most of the organic matter in the sewage. The cleaner water trickles out through pipes in the bottom of the filter.
>
> A typical overall efficiency of a trickling-filter treatment plant is about 85 percent removal of BOD and suspended solids for municipal wastewaters, which corresponds to about 30 mg/l of suspended solids and BOD in the final effluent.
>
> ACTIVATED SLUDGE - The activated-sludge process is a biological wastewater treatment technique in which a mixture of wastewater and biological sludge (micro-organisms) is agitated and aerated. Microorganisms grow through use of the organics and are mixed by the agitation of the air. Individual organisms clump together (floculate) to form an active mass of microbes called "activated sludge". The mixed liquor flows from the aeration tank to a secondary clarifier where the activated sludge is settled out. Most of the settled sludge is returned to the aeration tank to maintain a high population of microbes to permit rapid breakdown of the organics. Because more activated sludge is produced than can be used in the process, some of the return sludge is diverted or "wasted" to the sludge-handling system for treatment and disposal. Typical effluent quality is 20-25 mg/l BOD and 20-25 mg/l suspended solids, although, with careful operation, the process has produced less than 10 mg/l BOD and suspended solids at some plants. The process is usually lower in capital costs than a trickling-filter plant and requires less area.
>
> There are many variations of this conventional system that have evolved over the years and that have improved the process performance. The reader is referred to Environmental Pollution Control Alternatives: Municipal Wastewater, U.S. E.P.A., Technology Transfer, for a further discussion of the variations of this process.

OXIDATION PONDS - Oxidation ponds (also called "lagoons" or "stabilization ponds") are large shallow ponds designed to treat wastewater through the interaction of sunlight, wind, algae, and oxygen. They are one of the most commonly employed secondary systems and account for about one-third of all secondary plants in the United States. About 90 percent of the ponds are used in towns with less than 10,000 people (1-mgd capacity). Typically, raw wastewater enters the pond at a single point in the middle of the pond or at one edge. Algae grow by taking energy from the sunlight and consuming the carbon dioxide and inorganic compounds released by the action of the bacteria in the pond. The algae, in turn, release oxygen needed by the bacteria to supplement the oxygen introduced into the pond by wind action. The most critical factor is to insure that enough oxygen will be present in the pond to maintain aerobic conditions; if oxygen is insufficient, odor problems will occur. The sludge deposits from the pond eventually must be removed by dredging.

Oxidation ponds usually meet secondary treatment requirements for removal of BOD, but frequently fail to meet secondary requirements for suspended solids removal because of the presence of algae in the pond effluent. Much work is currently underway on various methods of removing these algae; the most promising alternatives to date are filtration through sand beds at low rates, filtration through a bed of rocks that may be a part of the dike system, and a combination of chemical treatment of the pond effluent and settling.

OTHER SECONDARY PROCESSES - There are two recently developed processes that do not fit precisely into the activated-sludge or trickling-filter categories, but do capitalize on some of the best features of both. These processes are rotating biological contactors and activated biofilters (also sometimes referred to as biodiscs or rotating biological surfaces).

BIODISCS -

ACTIVATED BIOFILTERS - involve the use of redwood slats and sludge recirculation. Microbes comparable to that in an activated-sludge system break down organic materials. Oxygen is supplied by the splashing of the wastewater between layers of the redwood slats and by the movement of the wastewater in a film across the microbial layer attached to the slats.

DISINFECTION - Disinfection is the killing of pathogenic (disease-causing) bacteria and viruses found in wastewaters. This process differs from sterilization, which is the killing of all living organisms. The last treatment step in a secondary plant is the addition of a disinfectant to the treated wastewater. The addition of chlorine gas or some other form of chlorine, which is called chlorination, is the process most commonly used for wastewater disinfection in the United States. Although there is concern about the formation of some byproducts resulting from chlorination, the use of chlorine has proven to be a very effective means of disinfecting wastewaters and water supplies. An alternative to chlorine is ozone, which is widely used in Europe for disinfection of water supplies. Ozone is produced at its point of use by passing dry air between two high-potential electrodes to convert oxygen into ozone. Recent improvements in the technology of ozone production have bettered the reliability and economy of its generation. The advantages of using ozone are that it has high germicidal effectiveness, which is the greatest of all known substances, and that the only residual material left in the wastewater is more dissolved oxygen.

The cost of the disinfection process is typically 1 cent per 1,000 gallons or less--so insignificant a portion of overall treatment costs that the minor difference in the cost of ozonation and chlorination is not an overriding factor in selection between these disinfection alternatives.

ADVANCED WASTEWATER TREATMENT--IN CASES WHERE SECONDARY LEVELS OF TREATMENT ARE NOT ADEQUATE, NEW TREATMENT PROCESSES ARE APPLIED TO THE SECONDARY EFFLUENT TO PROVIDE ADVANCED WASTEWATER TREATMENT, FOR FURTHER REMOVAL OF THE POLLUTANTS. SOME OF THESE PROCESSES MAY INVOLVE CHEMICAL TREATMENT AND FILTRATION OF THE WASTEWATER-MUCH LIKE ADDING A TYPICAL WATER TREATMENT PLANT TO THE TAIL END OF A SECONDARY PLANT--OR THEY MAY INVOLVE APPLYING THE SECONDARY EFFLUENT TO THE LAND IN CAREFULLY DESIGNED IRRIGATION SYSTEMS WHERE THE POLLUTANTS ARE REMOVED BY A SOIL-CROP SYSTEM. SOME OF THESE NEW PROCESSES CAN REMOVE AS MUCH AS 99 PERCENT OF THE BOD AND PHOSPHORUS, ALL SUSPENDED SOLIDS AND BACTERIA, AND 95 PERCENT OF THE NITROGEN. ALTHOUGH THESE PROCESSES AND LAND TREATMENT SYSTEMS ARE OFTEN APPLIED TO SECONDARY EFFLUENT FOR ADVANCED TREATMENT, THEY HAVE ALSO BEEN USED IN PLACE OF CONVENTIONAL SECONDARY TREATMENT PROCESSES.

THE FOLLOWING ARE SOME OF THE TECHNIQUES PRESENTLY IN USE IN ADVANCED WASTEWATER TREATMENT PLANTS FOR THE REMOVAL OF CERTAIN "PROBLEM" SUBSTANCES (EPA, 1976):

COAGULATION - Certain substances are not removed to any appreciable extent in conventional wastewater treatment facilities. Most notable is phosphorus but also some organic solids that create BOD loads on a stream escape the secondary treatment process. With relatively minor modifications to existing municipal wastewater treatment facilities, these substances can be removed from the effluent. Essentially, the modifications involve the addition of chemicals called "coagulants"--such as aluminum sulfate (alum), lime or ferric chloride. Coagulants cause the solids in wastewater to clump together; increasing their weight which allows them to settle faster. This clumping together of solids is accelerated by slowly stirring (flocculating) the wastewater after the coagulants have been added. The wastewater then enters a settling basin where the solids are dewatered, and then used in "controlled" land fill sites after settling. If the proper amount of coagulant is added, over 90 percent of the phosphorus and suspended solids normally present in a secondary effluent can be removed by this method.

FILTRATION - Filtration is the process of passing wastewater through a filtering medium, such as fine sand or coal, to remove suspended or colloidal matter. The goal of filtration in tertiary treatment is the removal of suspended solids from a secondary effluent or the effluent from the coagulation-sedimentation process. For example, the effluent from the tertiary coagulation and sedimentation typically will contain 3-5 mg/l suspended solids and 0.5-1.0 mg/l phosphorus. Efficient filtration of chemical effluent can reduce suspended solids to zero and phosphorus to 0.1 mg/l or less. Filtration of secondary effluents without chemical coagulation (plain filtration) is also used. Typically, plain filtration will reduce activated-sludge effluent suspended solids from 20-25 mg/l to 5-10 mg/l. Plain filtration is not effective on trickling-filter effluents, because the trickling-filter process is not as efficient in flocculating the microbes so that they are in a form readily removed by filtration.

Microscreening is another system used for filtration. Microscreens are mechanical filters that consist of a horizontally mounted drum, the cylindrical surface of which is made up of a special metallic filter fabric, and that rotates slowly in a tank with two compartments, so that water enters the drum from one end and flows out through the filtering fabric. The solids are retained on the inside of the rotating screen. Microscreens used in plain filtration applications can reduce activated-sludge-effluent suspended solids from 20-25 mg/l to 6-10 mg/l. Microscreens have an advan-

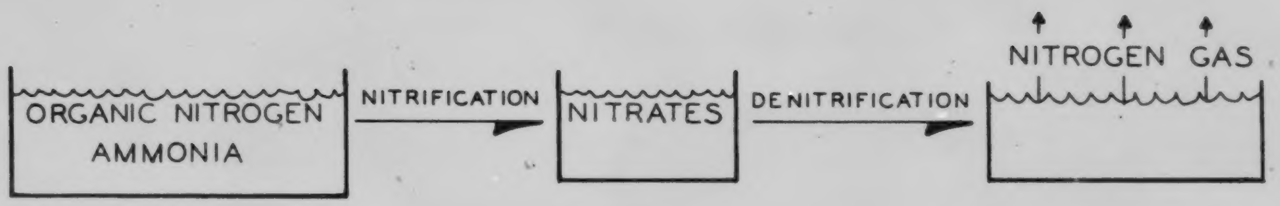


FIGURE 3. SCHEMATIC OF BIOLOGICAL NITRIFICATION-DENITRIFICATION PROCESS. (EPA, 1976)

tage over granular filters in that they operate continuously without the need for a separate backwashing cycle. They have the disadvantage of being more sensitive to variations in the incoming suspended solid concentrations, and they are not used for removal of chemical floc.

CARBON ADSORPTION - Even after secondary treatment, coagulation, sedimentation, and filtration, the soluble organic materials that are resistant to biological breakdown will persist in the effluent. The persistent materials are often referred to as "refractory organics", and are responsible for the color found in secondary effluent. Secondary effluent COD values are often 30-60 mg/l. The most practical available method for removing these materials is the use of activated carbon. Activated carbon removes organic contaminants from water by adsorption, which is the attraction and accumulation of one substance on the surface of another.

Granular carbon adsorption is achieved by passing the wastewater through beds of the carbon that may resemble a gravity filter or that may be housed in deep (20-25 foot) columns. These carbon beds usually provide 20-40 minutes contact between the carbon and the wastewater.

NITROGEN CONTROL - It is now apparent that ecological imbalances in the natural environment have been caused, in part, by the excessive discharges of nitrogeneous materials to natural waterways. In certain forms, nitrogen is one of the major nutrients supporting blooms of green and blue-green algae in surface waters. Nitrogen not only has nutrient value, but, in its various forms, can represent as much as 70 percent of the total oxygen demand of conventionally treated municipal wastewater.

During conventional biological wastewater treatment, almost all the nitrogen contained in the wastewater is converted into ammonia nitrogen. Although ammonia has very little toxicity to humans, treated wastewater effluent containing ammonia has several undesirable features: 1) it consumes dissolved oxygen in the receiving water; 2) it can be toxic to fish life; 3) it is co-rosive to copper fittings; 4) it increases the amount of chlorine required for disinfection.

Ammonia nitrogen can be reduced in concentration or removed from wastewater by several processes. These processes can be divided into two broad categories: biological methods and physical-chemical methods.

BIOLOGICAL METHODS:

Biological Nitrification-Dentrification. This process is the biological conversion of organic matter containing nitrogen into inorganic nitrate (nitrification), followed by the conversion of the nitrates to nitrogen gas (dentrification) by anaerobic bacteria (Figure 3). The process is based on the principle that the nitrogen compounds found in raw sewage may be converted to the nitrate form in a properly designed secondary biological process (the nitrification process). These nitrates may then be removed by further treatment in the absence of oxygen. Under these anaerobic conditions, the nitrogen

220

is released as nitrogen gas (the dentrification process). Because nearly 80 percent of the atmosphere consists of nitrogen, there is no air pollution associated with the release of nitrogen from the wastewater to the atmosphere.

In some cases, carrying out only the nitrification portion of the process may be adequate. Nitrification is accomplished by providing oxygen in the amount required in the biochemical reaction to convert ammonia nitrogen to nitrate nitrogen, or roughly 4.5 pounds of oxygen per pound of ammonia nitrogen in the wastewater.

The efficiency of biological nitrification-dentrification is usually 80-90 percent nitrogen removal.

PHYSICAL-CHEMICAL METHODS:

Ammonia Stripping. This process removes gaseous ammonia from water by agitating the water-gas mixture in the presence of air. In practice, the process is based on the principle that nitrogen in the form of ammonium ions in secondary effluent can be converted to ammonia gas by raising the pH to high values. The gaseous ammonia can then be released by passing the high-pH effluent through a stripping tower where the agitation of the water in the presence of a large air flow through the tower releases the ammonia. The use of lime in coagulation-sedimentation permits simultaneous coagulation for suspended solids and phosphorus removal and the necessary upward adjustment of pH for the stripping process.

The three basic steps in ammonia stripping are (1) raising the pH of the water to form ammonia gas, generally with the lime used for phosphorus removal, (2) cascading the water down through a stripping tower to release the ammonia gas, and (3) circulating large quantities of air through the tower to carry the ammonia gas out of the system. The towers used for ammonia stripping closely resemble conventional cooling towers. The concentration of ammonia in the offgas from the tower is very low--well below odor levels--and does not cause air pollution problems.

Selective Ion Exchange. By this process, ammonium ions in solution are exchanged for sodium or calcium ions displaced from an insoluble exchange material. The process operation resembles that of a water softener, except that the material being removed is ammonium-nitrogen rather than water hardness. The selective ion-exchange process derives its name from the use of an ion-exchange material that selectively removes ammonium. The ion-exchange material is a naturally occurring zeolite called "clinoptilolite".

The process is very efficient and can remove 95-97 percent of the ammonium nitrogen.

Breakpoint Chlorination. In this process, chlorine is added to wastewater in such amounts that the chlorine demand is satisfied so that further addition of chlorine results in a directly proportional chlorine residual. It is used for nitrogen removal because chlorine, when added to wastewater containing ammonium nitrogen, reacts to form compounds that, if enough chlorine is added, eventually are converted to nitrogen gas. To achieve the conversion, about -0 mg/l of chlorine must be added per mg/l of ammonia nitrogen in the wastewater. A typical secondary effluent ammonia concentration of 20 mg/l requires the use of about 1,700 pounds of chlorine per million gallons treated--about 40 or 50 times more than normally used in a wastewater plant for disinfection only.

Land Treatment. An alternative to the previously discussed processes for producing an extremely high-quality effluent is offered by an approach called "land treatment". Land treatment is the application of effluents, usually following secondary treatment on the land by one of the several available conventional irrigation methods. This approach uses wastewater, and often the nutrients it contains, as a resource rather than considering it as a disposal problem. Treatment is provided by natural processes as the effluent moves through the natural filter provided by the soil, plants, and related ecosystem. Part of the wastewater is lost by evapotranspiration, while the remainder returns to the hydrologic cycle through overland flow or the ground water system. Most of the ground water eventually returns, directly or indirectly, to the surface water system.

Land treatment of wastewaters can provide moisture and nutrients necessary for crop growth. In semiarid areas, insufficient moisture for peak crop growth and limited water supplies make water especially valuable. The primary nutrients (nitrogen, phosphorus, and potassium) are reduced only slightly in conventional secondary treatment processes, so that most of these elements are still present in secondary effluent. Soil nutrients are consumed each year by crop removal and lost by soil erosion. Fertilizer supply is highly dependent on energy input, and recently has increased significantly in price. Recycling wastes to the land so that the nutrient cycle can be completed and soil fertility maintained is an alternative that should be given serious consideration.

When properly designed and operated, a land treatment system of the irrigation type can produce an effluent quality comparable to that produced by other tertiary treatment processes for phosphorus, suspended solids, BOD, heavy metal, virus, and bacterial removal. Comparable nitrogen removals can also be produced, but the nitrogen removal achieved in a land treatment system depends directly on the specific design and operating procedures used. For example, while phosphorus is readily removed by chemical reactions with the soil, the chief mechanism for nitrogen removal is uptake by crops. High degrees of nitrogen removal require that wastewater be applied to the land only during the season of active crop growth. In many parts of the country, this requirement and the need to avoid applying wastewater to frozen land frequently dictate that storage lagoons with capacity to store 3-5 months of wastewater be constructed to store wintertime wastewater flows. Land treatment also efficiently removes heavy metals. These metals may accumulate and persist in the soil, however, and their long-term effects must be evaluated carefully for the specific wastewater and soil conditions involved.

SLUDGE TREATMENT AND DISPOSAL - IN THE PROCESS OF PURIFYING THE WASTEWATER, ANOTHER PROBLEM IS CREATED -- SLUDGE HANDLING. THE HIGHER THE DEGREE OF WASTEWATER TREATMENT, THE LARGER THE RESIDUE OF SLUDGE THAT MUST BE HANDLED. SATISFACTORY TREATMENT AND DISPOSAL OF THE SLUDGE CAN BE THE SINGLE MOST COMPLEX AND COSTLY OPERATION IN A MUNICIPAL WASTEWATER TREATMENT SYSTEM. THE SLUDGE IS MADE OF MATERIALS SETTLED FROM THE RAW WASTEWATER--SUCH AS RAGS, STICKS, AND ORGANIC SOLIDS--AND OF SOLIDS GENERATED IN THE WASTEWATER TREATMENT PROCESSES--SUCH AS THE EXCESS ACTIVATED SLUDGE CREATED BY AERATION OR THE CHEMICAL SLUDGES PRODUCED IN SOME AWT PROCESSES. WHATEVER THE WASTEWATER PROCESS, THERE IS ALWAYS SOMETHING THAT MUST BE BURNED, BURIED, TREATED FOR REUSE, OR DISPOSED OF IN SOME WAY.

THE QUANTITIES OF SLUDGE INVOLVED ARE SIGNIFICANT. FOR PRIMARY TREATMENT, THEY MAY BE 2,500-3,500 GALLONS PER MILLION GALLONS OF WASTE-WATER TREATED. WHEN TREATMENT IS UPGRADED TO ACTIVATED SLUDGE, THE QUANTITIES INCREASE BY 15,000-20,000 GALLONS PER MILLION GALLONS. USE OF CHEMICALS FOR PHOSPHORUS REMOVAL CAN ADD ANOTHER 1,000 GALLONS. SLUDGES WITHDRAWN FROM THE TREATMENT PROCESSES ARE STILL LARGELY WATER, AS MUCH AS 97 PERCENT! TO MAKE SLUDGE DISPOSAL MORE EFFICIENT, THIS WATER MUST BE REDUCED. SLUDGE TREATMENT PROCESSES, THEN, ARE CONCERNED WITH SEPARATING THE LARGE AMOUNTS OF WATER FROM THE SOLID

RESIDUES AS WELL AS DISPOSING OF THE SOLIDS. THIS SEPARATION CAN BE ACCOMPLISHED BY

conditioning - (treatment of the sludge with chemicals or heat so that the water may be readily separated);

thickening - (removal of water by gravity or flotation process);

dewatering - (further separation of water by subjecting the sludge to vacuum pressure, or drying processes);

stabilization - (treating organic solids so that they may be handled or used as soil conditioners without causing a nuisance or health hazard); and

reduction - (changing the solids to a stable form by wet oxidation processes or incineration).

ALTHOUGH A LARGE NUMBER OF ALTERNATIVE COMBINATIONS OF EQUIPMENT AND PROCESSES ARE USED FOR TREATING SLUDGES, THE BASIC ALTERNATIVES ARE FAIRLY LIMITED. THE ULTIMATE DEPOSITORY OF THE MATERIALS CONTAINED IN THE SLUDGE MUST EITHER BE LAND, AIR, OR WATER. CURRENT POLICIES DISCOURAGE PRACTICES SUCH AS OCEAN DUMPING OF SLUDGE. AIR POLLUTION CONSIDERATIONS NECESSITATE AIR POLLUTION FACILITIES AS PART OF THE SLUDGE INCINERATION PROCESS. THUS, THE SLUDGE IN SOME FORM WILL EVENTUALLY BE RETURNED TO THE LAND.

THE READER IS REFERRED TO ENVIRONMENTAL POLLUTION CONTROL ALTERNATIVES: MUNICIPAL WASTEWATER, US EPA, TECHNOLOGY TRANSFER, 1976 FOR FURTHER READING ON SLUDGE DISPOSAL.

UNSEWERED TREATMENT FACILITIES

UNSEWERED WASTEWATER TREATMENT FACILITIES CAN BE DIVIDED INTO TWO BROAD CATEGORIES DEPENDING UPON WHETHER ACTUAL ON-SITE TREATMENT AND DISPOSAL OF THE WASTE WILL OCCUR, AND ON THEIR WASTEWATER DELIVERY SYSTEMS.

HOLDING TANKS - Those systems where on-site treatment and disposal is not a factor are lumped under the term "holding tanks". Holding tanks are primarily used in areas where soils, topography, and/or population densities make on-site disposal systems inoperable or even dangerous to human health (due to pathogenic contamination of groundwater). Wastewater entering this system is transported by water and may be of the "black" (i.e. toilet wastes) or "gray" (kitchen, bathing, and laundry wastewater) water variety. Holding tanks simply contain the wastewater in a closed system until it is pumped out and transported to a municipal treatment facility. No physical or biological treatment of the wastes occurs.

ON-SITE TREATMENT DISPOSAL SYSTEMS CAN BE SUBDIVIDED ON THE BASIS OF THEIR SEPTIC DELIVERY SYSTEMS (TABLE XII).

223

TABLE XII. A BREAKDOWN OF UNSEWERED WASTEWATER SYSTEMS ON THE BASIS OF THEIR WASTEWATER DELIVERY SYSTEM.

	UNSEWERED WASTEWATER SYSTEMS	
	FLUSH TOILET USING WATER MEDIUM	TOILET USING DELIVERY MECHANISM OTHER THAN WATER
TYPE OF SYSTEM	SEPTIC TANKS HOLDING TANKS AEROBIC TREATMENT UNITS	COMPOSTING TOILETS INCINERATING TOILETS BIOLOGICAL TOILETS RECIRCULATING OIL FLUSH TOILET
WASTEWATER HANDLED	BLACK AND GRAY WATER TREATMENT	BLACK WATER TREATMENT ONLY
OTHER CONSIDERATIONS	NO ADDITIONAL SYSTEMS NEEDED	ADDITIONAL GRAY WATER SYSTEM NEEDED

SEPTIC TANKS AND AEROBIC TREATMENT UNITS UTILIZE WATER TO TRANSPORT WASTES. THESE SYSTEMS CAN HANDLE ALL TYPES OF DOMESTIC EFFLUENT--I.E., "BLACK" AND "GRAY" WASTEWATER. SYSTEMS THAT DO NOT USE WATER AS A TRANSPORTING MEDIA INCLUDE TOILETS THAT INCINERATE, COMPOST, BIOLOGICALLY DEGRADE, OR RECIRCULATE OIL IN THE BREAKDOWN OR MOVEMENT OF WASTES. THESE LATTER SYSTEMS CAN ONLY EFFICIENTLY HANDLE "BLACK" WATER; AS A RESULT, AN ADDITIONAL "GRAY" WATER SYSTEM MUST BE USED IN CONJUNCTION WITH THESE SYSTEMS.

SEPTIC SYSTEMS - Septic systems service over 16 million housing units in the United States today--over 25 percent of all houses in the U.S.. Septic systems are used where low housing density cannot economically justify sewers and expensive wastewater treatment plants.

A septic system typically consists of a buried tank and a subsurface drain system. (Figure 4) Wastewater effluents enter the tank where they remain for several days. During this period, grease, scum, and solid materials settle to the bottom of the tank and are attacked by anaerobic (oxygen-free) bacteria. Liquid effluents pass out of the tank into a subsurface drain system where they perculate into the soil. Biological processes and natural absorption capacities of the soil result in the breakdown of bacteria, viruses, and nutrients from the effluent.

Maintenance of the system requires periodic pump-out of the septic tank to remove accumulated solids. Build up of biological slimes, bacteria, or solids occasionally clog the subsurface drain system. Two soil absorption fields that can be alternated every six months or the use of strong oxydizing agents, e.g., hydrogen peroxide, can be used to minimize clogging problems. In areas where septic systems have been in operation for many years and the effectiveness of absorption beds are questionable, a community may opt for a cluster septic system. Under such a system, each household

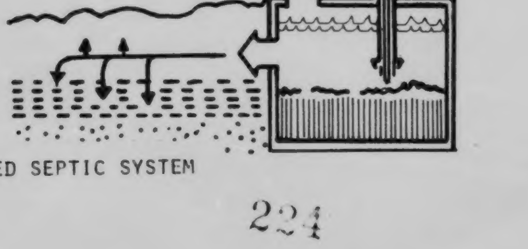


FIGURE 4. A GENERALIZED SEPTIC SYSTEM

maintains its septic tank for on-site disposal of solids but the liquid portion is transported to a community leaching field.

Effectiveness of the septic system depends on three factors: design, installation, and maintenance. Septic tanks and drain systems should have a capacity to meet anticipated water consumption demands, and a tank detention time to insure settling of solids before passage of the effluent to the field drainage system. Drainage system configurations should comply with state standards for area and site factors. In general, the best installation sites are located on nearly level, deep and well-drained loam or sandy loam soils. Sites that are on shallow or coarse textured soils will not allow sufficient time for water perculation and biological removal of pathogens and nutrients. Siting of septic systems on fine-textured soils will result in inadequate perculation rates through the soil profile; this results in a "back-up" of the system and saturation of the soil field above the drain system. Systems placed on steep slopes or soils with a high water table will observe wastewater flowing out to the surface and/or down the slope.

New options in septic system design include evapo-transpiration/mound systems and pressure distribution systems.

Pressure distribution involves the build up of a wastewater "head" that results in the release of a large volume of water to the absorption field rather than a continuous trickle. The "dosing effect" results in better distribution of wastewater over the entire seepage area and prevents clogging of the absorption field in the area of the outlet drain from the septic tank. In Wisconsin the pressure distribution system is now recommended for all new septic systems and is required in septic systems with capacities greater than 1500 gallons.

The evapo-transpiration/mound system (Figure 5) has received considerable interest because it could open up large, previously restricted areas to housing development. The mound system was designed for use in areas containing bedrock near the surface, slowly permeable soils, or high groundwater. A soil-covered seepage bed is placed above a layer of sandy fill which is built over the original soil surface. A pump transports the household wastes into the mound in a "dosing" manner; this improves wastewater distribution. The extra mound soil improves effluent renovation before the discharge reaches the original topsoil. Plants over the mound increase the evapo-transpiration rate, lifting the effluent up from the distribution pipe and into cleansing soil. The mound must be carefully designed to prevent early clogging; the dosing rate must not overburden the mound percolation rate. Mound systems are relatively new in the Lake Michigan area. Although unsuccessful in Pennsylvania, where they originated, design modification and careful construction have made them a viable alternative in areas where holding tanks were once considered the only satisfactory means for handling wastewater. Since 1976, sixty-five mound systems have been in operation in Wisconsin. A disadvantage of the system is cost; it is estimated that a mound system averages 3-4 times the price of a conventional system.

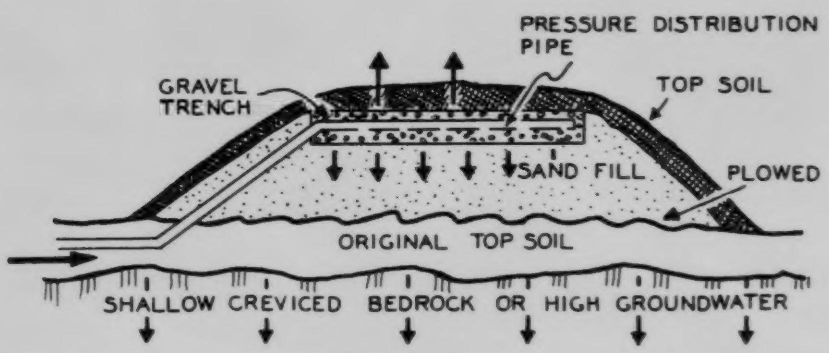

PRESSURE DISTRIBUTION PIPE
GRAVEL TRENCH
TOP SOIL
SAND FILL
PLOWED
ORIGINAL TOP SOIL
SHALLOW CREVICED BEDROCK OR HIGH GROUNDWATER

FIGURE 5. A MOUND SYSTEM

OTHER LESS COMMON, ON-SITE DISPOSAL SYSTEMS FOLLOW.

AEROBIC TREATMENT UNITS - This system is similar to a septic tank, except that there are typically three compartments instead of two. A conventional flush toilet transports the wastes. In the additional chamber, an electrically driven air compressor vigorously injects air beneath the surface of the wastewater to promote aerobic digestion by a resident population of bacteria. This aerobic digestion produces an effluent that is less polluted than that from a septic tank and thereby requires a smaller drainage field.

Aerobic treatment units require the same maintenance as septic tanks to function effectively. They must have sludge pumped out periodically, and, drainage fields must be protected from clogging. Most units depend upon an air compressor which needs periodic servicing to prevent breakdown.

The cost of an aerobic unit ranges from about $850 to install a unit on an existing septic tank to about $1,500 for a complete unit.

WATERLESS COMPOSTING TOILETS - These toilets decompose human waste, toilet tissue, and kitchen scraps by using aerobic microorganisms to produce a humus-like material. No water is used in the transport process.

The most well-known waterless composting toilet is the Clivis Multrum. The system is composed of a 10-foot long sloping fiberglass box (lined with a starter layer of peat moss and topsoil) that is divided into three compartments. Toilet wastes fall into the upper compartment, and kitchen garbage (only organic materials) fall into the middle compartment, whereupon the combined wastes decompose simultaneously. Accumulating wastes slide down the sloping bottom at a rate slow enough to insure that they will be decomposed by the time they reach the final storage chamber. Aerovic bacteria found in the initial soil layer start the decomposition process, which continues as human waste and garbage containing more oxygen-loving bacteria are added.

Air inlets within the box keep the decomposition process aerobic. Wind action across the top of a vertical ventilation pipe connecting the box to the outside increases circulation. Exhaust from the unit consists mainly of carbon dioxide and water vapor. Odors are prevented by the continuous downward draft into the container whenever the toilet or garbage disposal lids are open. During periods of low wind velocities odors can be avoided by installing a small auxiliary fan.

It takes 2-4 years before humus develops in the final storage chamber. After that, 3-10 gallons of humus are generated per person per year--a fraction of the volume originally deposited. According to the manufacturers, 3 pounds (dry weight) of this compost is roughly equivalent to 1 pound of "10-10-10" fertilizer and is very low in pathogenic bacteria numbers.

The advantages of such composting toilets are that they are completely waterless, require little maintenance, require little or no energy, and are environmentally sound.

The disadvantages include high initial costs ($1,500-$1,700 for the bi-level); the space requirements of the box itself; and the present resistance of some public health officials to accept this unconventional waste disposal method. As more scientific information becomes available, further acceptance of the composting toilet may occur.

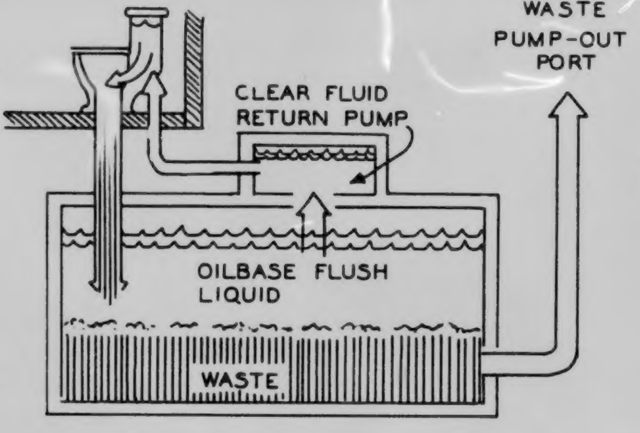
INCINERATING TOILETS - This system employs high temperatures, generated by oil, electricity, natural gas, or propane, to reduce wastes to a sterile ash. Most models incorporate a self-contained, above-the-floor design that requires only a fuel source and vent stack to install. A forced air exhaust blower provides ventilation.

Advantages and disadvantages of this system is that maintenance is generally minimal, amounting to periodic removal of ash residue from the oxidation chamber. Some units, however, are highly automated, increasing the chances of something going wrong. The initial cost of an incinerating toilet ($500-$900) is moderate compared to some other systems, but they require a considerable amount of energy. The estimated annual energy costs range from $40-$95 per person per year.

BIOLOGICAL TOILETS - The action of enzymes and both aerobic and anaerobic bacteria are used in this system to break down human wastes. A charcoal filter bed recycles and filters water within the toilet, so that no water is needed beyond the 15 gallons which start up the unit. The system produces approximately one quart of effluent per user each week. Installation involves an updraft vent stack to the outside. Maintenance requires a weekly package of freeze-dried enzymes and bacteria. The unit is moderately priced ($500); the main disadvantage of it is a slight odor.

RECIRCULATING OIL FLUSH TOILETS - The recirculating oil flush toilet is based on the principle that human wastes are heavier than oil (Figure 6). Oil is the medium used to carry wastes from the toilet bowl to a settling tank. Once in the tank, heavier, water-saturated wastes sink to the bottom, and the lighter oil is drawn off the surface, filtered, and recirculated to the toilet. The settled wastes must then be periodically removed. This type of system is complex and expensive ($5,000-$10,000) and demands regular maintenance. For these reasons, its use so far has been limited mainly to public buildings.

FIGURE 6. AN OIL FLUSH TOILET SYSTEM



SUMMARY

All waterless toilets must also have some accompanying system to provide for the treatment of gray water--the wastewater from bathing, laundry, and kitchen. Because gray water is generally less contaminated than black water, on-site treatment is generally a simpler task than for combined household wastewater.

CONCLUSION

IT SHOULD BE APPARENT FROM THIS DISCUSSION THAT THERE ARE MANY ALTERNATIVES AVAILABLE FOR WASTEWATER TREATMENT. THE ACTUAL SYSTEM SELECTED, HOWEVER, WILL DEPEND ON A NUMBER OF FACTORS NOT THE LEAST OF WHICH IS THE AVAILABILITY OF SEWER LINES TO EXISTING TREATMENT PLANTS. IF SEWERS ARE UNAVAILABLE, THEN THE SELECTION OF A WASTEWATER TREATMENT UNIT WILL LARGELY DEPEND ON THE HOMEOWNER'S PREFERENCES AND THE SITE CONDITIONS. IF SEWER LINES ARE AVAILABLE, THEN THE FOLLOWING CONSIDERATIONS SHOULD BE MADE (EPA, 1976):

NATURE OF THE RAW WASTES - Current or future industrial wastes could have a significant effect on the capacity and performance of the treatment facility. Industrial pretreatment requirements may minimize these effects, but the process should be flexible enough to accommodate variations in pretreatment efficiency.

EFFLUENT REQUIREMENTS - The required effluent quality has an obvious, major impact on process selection in large wastewater treatment facilities.

PROCESS RELIABILITY - It is important that the processes selected provide the maximum degree of reliability.

SLUDGE PRODUCTION - The ability to handle sludges produced by a candidate process in an economical and environmentally satisfactory manner is also a critical factor in process evaluation.

AIR POLLUTION - A careful evaluation of the ultimate fate of pollutants removed from the wastewater must be made to insure that water pollution control has not been achieved at the expense of air pollution.

RESOURCE CONSUMPTION - Wastewater treatment cannot be achieved without the expenditure of resources such as power and chemicals. It is obviously desirable to minimize the consumption of these resources, and the relative consumption by alternative processes is a factor for consideration.

SPACE REQUIREMENTS - The relative space requirements of alternative processes are a factor in process selection.

SAFETY CONSIDERATIONS - Any potential hazards within treatment site boundaries, or those which could affect the surrounding area as a result of system malfunction or transport of materials to or from the system must be considered. In the case of on-site disposal system, consideration of soils, topography, a system capacity and design is critical for a safe and efficient operation of the system.

COSTS - It is obviously important to select a process that can achieve the project goals in the most cost-effective manner within the constraints imposed by the foregoing considerations.

TABLE XI Evaluation of Wastewater Treatment Processes (6, pp. 101-103)

Treatment Process	Application	Advantages and Capabilities	Disadvantages and Limitations
1. PRETREATMENT			
a. Equalization	Waste streams with high variability	1. Dampens waste variations. 2. Reduces chemical requirements. 3. Dampens peak flows, reduces treatment plant size.	1. Need large land areas. 2. Possible septicity, requiring mixing and/or aeration equipment.
b. Neutralization	Waste streams with extreme pH values	1. Provides the proper conditions for biological, physical chemical treatment. 2. Reduces corrosion and scaling.	1. May generate solids. 2. Sophisticated equipment and instrumentation.
c. Temperature adjustment	Waste streams with extreme temperatures	Provides the proper conditions for biological treatment.	High initial equipment costs.
d. Nutrient additions	Nutrient deficient wastes	Optimizes biological treatment.	
2. PRIMARY TREATMENT			
a. Screening	Waste streams containing large solids (wood, rags, etc.)	1. Prevents pump and pipe clogging. 2. Reduces subsequent solids handling.	1. Maintainence required to prevent screen plugging, ineffective for sticky solids.
b. Grit removal	Waste streams containing significant amounts of large, heavy inorganic solids.	1. Lowers maintenance costs, erosion. 2. Reduces the solids loading to other treatment units.	1. Solids to be disposed of are sometimes offensive.
c. Sedimentation	Waste streams containing settleable suspended solids.	1. Reduces inorganic and organic solids loadings to subsequent biological units. 2. By far the least expensive and most common method of solid-liquid separation. 3. Suitable for treatment of a wide variety of wastes. 4. Requires simpler equipment and operation. 5. Demonstrated reliability as a treatment process.	1. Possible septicity and odors. 2. Adversely affected by variations in the nature of the waste. 3. Moderately large area requirement.
d. Dissolved-air flotation	Waste streams containing oils, fats, suspended solids and other flotable matter. Can be used for either clarification or thickening.	1. Removes oils, greases, and suspended solids. 2. Less tank area than for a sedimentation tank. 3. Higher concentration of solids than for sedimentation. 4. Satisfies immediate oxygen demand. Maintains aerobic conditions.	1. High initial equipment costs. 2. Sophisticated equipment and instrumentation. 3. High power and maintenance cost.

3. SECONDARY TREATMENT			
a. Activated sludge (aeration and secondary sedimentation)	Biologically treatable organic wastes	1. Flexible - can adapt to minor pH, organic and temperature changes. 2. Produces high quality effluent 90% BOD and suspended solids removal. 3. Small area required. 4. The degree of nitrification is controllable. 5. Relatively minor odor problems.	1. High operating costs (skilled labor, electricity etc.) 2. Generates solids requiring sludge disposal. 3. Some process alternatives are sensitive to shock loads, and metallic or other poisons. 4. Requires continuous air supply.
b. Aerated lagoon	Biologically treatable organic wastes	1. Flexible-can adapt to minor pH, organic, and temperature waste changes. 2. Inexpensive construction 3. Minimum attention. 4. Moderate effluent (50-75% BOD removal)	1. Dispersed solids in effluent. 2. Affected by seasonal temperature variations. 3. Operating problems (ice, solids settlement, etc.). 4. Moderate power costs. 5. Large area required. 6. No color reduction.
c. Oxidation pond	Biologically treatable organic wastes	1. Low construction costs 2. Non-skilled operation. 3. Moderate quality effluent (70-85% BOD removal) 4. Removes some nutrients from wastewaters	1. Large land area required 2. Algae in effluent 3. Possible septicity and odors 4. Weed growth, mosquito, and insect problems 5. Large area requirements.
d. Trickling filter	Biologically treatable organic wastes	1. Moderate quality effluent (80-85% BOD removal) 2. Moderate operating costs (lower than activated sludge and higher than oxidation pond). 3. Withstands shock loads better than other biological systems.	1. High capital costs. 2. Clogging of distributors or beds. 3. Snail, mosquito, and insect problems.
e. Chemical oxidation	Low flow, high concentration wastes of known and consistent waste composition, or removal of refractory compounds.	1. Disinfects effluents. 2. Aids grease removal. 3. Removes taste and odor producing compounds. 4. Removes organics without producing a residual waste concentrate	1. Chemical costs. 2. High initial equipment costs. 3. Skilled operation. 4. Requires handling of hazardous chemicals.

3. SECONDARY TREATMENT
(continued)

Treatment Process	Application	Advantages and Capabilities	Disadvantages and Limitations
f. Spray irrigation	Non-toxic, dissolved wastes.	1. Inexpensive initial cost. 2. Minimum operator attention.	1. Pollutional removal undefined. 2. Large land area required. High ground porosity needed. 3. Possible contamination of potable aquifers. 4. Freezing in winter. 5. Odors in summer.
g. Chemical mixing flocculation and clarification	Waste stream high in dissolved solids, colloids, metals, or precipitable inorganics and waste containing emulsufied oils.	1. Removes metallic ions, nutrients, colloids, dissolved salts. 2. Recovery of valuable materials. 3. Provides proper conditions for biological treatment.	1. Sophisticated equipment and instrumentation. 2. Residual salts in effluent. 3. Produces considerable sludge.
h. Gravity filtration	Waste streams with organic or inorganic suspended solids, emulsions, colloids.	1. Breaks emulsions. 2. Removes suspended solids.	1. Clogging. 2. Frequent backwashing.
i. Pressure filtration	Waste streams high in suspended solids (i.e., sludges, organic solids)	1. High solids removal (75-30%).	1. High equipment costs. 2. Clogging. 3. High pressure drop (power costs)
j. Dissolved-air flotation with chemicals	Waste streams containing oils, fats, colloids, and chemically coalesced materials	1. Produces high degree of treatment. 2. Removes oils, greases, colloids.	1. High initial equipment costs. 2. High operations cost. 3. Sophisticated instrumentation.
k. Anaerobic contact	Waste streams with high BOD and/or high temperature	1. Methane recovery. 2. Small area required. 3. Volatile solids destruction.	1. Heat required. 2. Effluent in reduced chemical form, requires further treatment. 3. Sludge disposal. 4. Requires skilled operation.
4. TERTIARY TREATMENT			
a. Foam fractionation	Surface active agents (waste streams with high surface tension materials, i.e., anionic ABS)	1. Reduces refractory organics. 2. Reduces foaming tendencies of effluent.	1. Operational costs (air) 2. Only moderate removal (30-40% of total organics in secondary effluent)

b. Activated carbon absorption	Waste streams containing trace amounts of organics and color, taste, and odor producing compounds	1. Removes non-biodegradable organics from wastewaters. 2. Removes taste and odor producing compounds. 3. Reduces color.	1. High equipment costs 2. Carbon costs- a. pH adjustment b. Initial carbon c. Make-up carbon 3. No inorganic removal 4. Wastes must be solid-free to prevent clogging. 5. Air pollution potential when regenerating activated carbon. 6. Limited throughout.
c. Stripping	Waste streams containing dissolved gases, volatile organics and materials that can be chemically converted to gases.	1. Removes gaseous or volatile substances. 2. Reduces odors. 3. Chemical recovery (i.e., sulfur).	1. High initial equipment costs. 2. Fuel costs. 3. Requires pH adjustments. 4. Possible air pollution.
d. Evaporation 1. Solar	Dissolved salts in concentrated solutions as well as general wastewaters.	1. Low initial cost. 2. Inexpensive operation. 3. Waste volume reduction.	1. Large land area. 2. Dependent on geographical location for evaporation. 3. Solids disposal.
2. Artificial	Dissolved concentrated salts.	1. Waste volume reduction 2. By product recovery	1. Equipment costs. 2. Corrosion and scaling. 3. Heat requirements
e. Distillation	1. Concentration of inorganic and organic materials 2. Separation of inorganic and materials from product water.	1. By product recovery. 2. Incineration of concentrations. 3. Extremely high effluent quality (5 mb/L total dissolved solids); non-selective.	1. Equipment costs. 2. Skilled labor. 3. Energy costs. 4. Maintenance costs (corrosion). 5. Possible air pollution. 6. Extremely nigh capital and operating costs; volatile matter and ammonia carryover at normal pH; complex equipment and operation; requires pretreatment for removal of suspended solids.
f. Ion exchange	1. Demineralization 2. Concentration of ionized organics or inorganics.	1. Inorganic removal 2. By-product recovery. 3. Compact equipment. 4. Selectively concentrates organics and inorganic material.	1. High equipment costs. 2. Skilled labor. 3. Chemical costs. 4. Organic fouling, requires pretreat-

4. TERTIARY TREATMENT
(continued)

Treatment Process	Application	Advantages and Capabilities	Disadvantages and Limitations
		5. Substitutes less objectionable ions for contaminants. 6. Reliable with equipment easily available. 7. Produces effluent with 30 mg/L total dissolved solids.	ment for removal of suspended solids. 5. Disposal of regenerate wastes (brine) 6. Subject to changes in raw waste composition. 7. Requires auxiliary chemicals for regeneration.
g. Freezing	1. Sea or brackish waters. 2. Dissolved inorganics.	1. Salt separation. 2. Possible by-product recovery.	1. High equipment costs. 2. High power costs. 3. Affected by traces of detergents.
h. Electrodialysis	1. Brackish waters. 2. Dissolved inorganics in 750-7500 mg/L concentrations.	1. Removes inorganics and some organics 2. By-product recovery. 3. Compact equipment. 4. Reduces dissolved solids (40-50%). 5. Proven plant scale performance.	1. High initial costs. 2. Skilled labor. 3. High power costs. 4. Fouling a. Requires removal of suspended solids and dissolved organic solids. b. Membrane cleaning and replacement. 5. Sophisticated equipment and instrumentation. 6. Produces excess brine.

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He is married and has two daughters. Among his hobbies are fruit farming, jogging, winterness camping, and river running.

GLOSSARY

BEST AVAILABLE TECHNOLOGY (BAT): more stringent effluent guidelines to create uniformity among dischargers and to achieve "zero discharge" by 1985. These are being developed to apply to existing point sources by no later than July 1, 1983.

BEST PRACTICABLE TECHNOLOGY (BPT): minimum compliance under law to be achieved by July 1, 1977 and based on the best existing performance by well-operated plants.

BOILER FEEDWATER: water that is converted to steam.

COOLING WATER: water used to cool some process or material and which does not come in contact with the product.

EFFLUENT GUIDELINES: performance standards set by the EPA for point sources. May take the form of "best practicable technology" standards (BPT); "best available technology" standards (BAT) and/or "new performance" standards.

NEW PERFORMANCE STANDARDS: resemble BAT guidelines but were developed to apply to new sources of pollution.

NPDES PERMITS: discharge permits required by all point source dischargers under the National Pollutant Discharge Elimination System which is operated by the EPA or EPA-approved states. A permit is normally good for five years.

PROCESS WATER: water used in the processing of a product that comes in contact with the material being processed and thus is contaminated to some extent.

SANITARY AND SERVICE WATER: water used for personnel needs, cleaning, and other plant uses.

THE INDUSTRIAL STAKE IN WATER QUALITY

Introduction

The availability of an abundant and reliable supply of high quality fresh water is an essential requirement for many--if not most--industries. Water is a critical resource. It is no accident that major industrial centers are located beside major rivers and lakes.

Utilization of water varies from industry to industry. Table I presents a 1973 estimate of fresh water used by major industrial components, not including utility cooling water.

Table I. Annual Water Use by Types of Industry.

Industry	Water Usage, BGD		
	Gross*	Intake	Discharge
Primary Metal Manufacture	24.2	13.5	13.1
Chemicals and Allied Products	30.4	11.4	10.7
Paper and Allied Products	22.3	6.6	6.3
Petroleum and Coal Products	32.0	3.5	3.2
Food	4.3	2.2	2.0
Transportation Equipment	5.4	0.7	0.6
Machinery	4.1	0.8	0.7
Textile Mill Products	1.2	0.5	0.4
All Industries	130.0	41.0	38.5

1972 Census of Manufacturers Estimates for 1973

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*The difference between gross usage and intake represents the success in conserving water by in-plant reuse (Kemmer, 1977).

Industry's use of water has increased seventeen times since 1900. During this same period, the U.S. population has increased about two and one-half times. This means that for each person, industry now uses six times as much water as it did in 1900. Whereas today the average person uses about 60-70 gallons per day in his home for drinking, cooking, washing, lawn-watering, etc., industry withdraws about 940 gallons per person per day.

IT IS DIFFICULT TO NAME ANY MAJOR INDUSTRY TODAY WHICH UTILIZES LITTLE WATER. THE AMOUNT OF WATER REQUIRED TO MAKE SOME PRODUCTS IS OFTEN ASTOUNDING; FOR EXAMPLE, ONE TON OF FINE BOOK PAPER REQUIRES 184,000 GALLONS OF WATER; ONE TON OF FINISHED STEEL CONSUMES 32,000 GALLONS; ONE GALLON OF GASOLINE REQUIRES 10 GALLONS OF WATER; AND IT TAKES 35 GALLONS TO PRODUCE ONE QUART OF 100-PROOF WHISKEY.

SOURCES AND USES OF INDUSTRIAL WATER

IT IS PROBABLY NOT SURPRISING THAT INDUSTRY OBTAINS 96 PER CENT OF ITS WATER FROM ITS OWN FACILITIES, WHILE ONLY 4 PER CENT IS PURCHASED FROM PUBLIC FACILITIES. A BREAKDOWN OF INDUSTRIAL WATER BY SOURCE, INCLUDING THE FUEL-ELECTRIC POWER INDUSTRY IS:

SURFACE WATER -- 160 BILLION GALLONS/DAY:
GROUND WATER -- 8 BILLION GALLONS/DAY; AND
PUBLIC SUPPLIES -- 8 BILLION GALLONS/DAY.

THE USES TO WHICH INDUSTRY PUTS WATER ARE INNUMERABLE. HOWEVER, IN GENERAL, THEY CAN BE BROKEN DOWN INTO FOUR AREAS: COOLING WATER; PROCESS WATER; BOILER FEEDWATER; AND SANITARY AND SERVICE WATER.

COOLING WATER IS USED TO COOL SOME PROCESS OR MATERIAL, BUT DOES NOT MAKE DIRECT CONTACT. PROCESS WATER, ON THE OTHER HAND, CONTACTS THE PRODUCT OR MATERIAL BEING PROCESSED AND VERY LIKELY IS CONTAMINATED TO SOME EXTENT WITH POLLUTANTS SUCH AS DIRT, OIL, AND GREASE. BOILER FEEDWATER IS WATER WHICH IS CONVERTED TO STEAM. SANITARY AND SERVICE WATER IS THAT WHICH IS USED FOR PERSONNEL NEEDS, CLEANING, AND OTHER PLANT USES.

ABOUT 90 PER CENT OF THE WATER WITHDRAWN BY INDUSTRY IS USED FOR COOLING. WHILE THIS WATER DOES NOT COME INTO CONTACT WITH FOREIGN SUBSTANCES, HEAT IS ALWAYS ADDED. THE TEMPERATURE RISE IN COOLING WATER WHICH PASSES THROUGH AN INDUSTRIAL PLANT IS USUALLY IN THE RANGE OF 5°-20°F AND SELDOM EXCEEDS 30°F. IN MOST INSTANCES, THE HEAT IS QUICKLY DISSIPATED BY THE RECEIVING STREAM OR LAKE.

LARGE POWER PLANTS, HOWEVER, CAN CREATE A PROBLEM SINCE MOST INDUSTRIAL COOLING WATER IS USED IN THIS APPLICATION. WHILE A SMALL AMOUNT OF WATER IS USED FOR BOILER FEED TO MAKE STEAM, THIS AMOUNT IS DWARFED BY THE WATER WHICH IS USED TO COOL THE CONDENSERS. CONDENSERS FOR THE SPENT STEAM ARE NECESSARY BECAUSE STEAM TURBINES OPERATE MOST EFFICIENTLY IF THE STEAM IS CONDENSED TO LIQUID WATER AFTER IT PASSES THROUGH THE CONDENSERS. REFINERIES, CHEMICAL PLANTS, AND STEEL PLANTS ARE ALSO LARGE USERS OF COOLING WATER.

THE MAJORITY OF MANUFACTURING PLANTS USE PROCESS WATER SOMEWHERE IN THE PRODUCTION PROCESS. IN SOME CASES, WATER IS PRESENT ALMOST EVERY STEP OF THE WAY TO A FINISHED PRODUCT. FOR EXAMPLE,

> "...in the production of pulp and paper, water is used for removing bark from pulp wood, moving the ground wood and pulp from one process to another, cooking the wood chips for removal of liquors

> and washing the pulp. The cooling liquors are made up of various chemicals, such as sodium sulfite and sodium hydroxide, that are dissolved in water." (Water and Industry, U.S. Dept. of Interior Geological Survey 0-457-795, p. 10).

OTHER INDUSTRIES WHICH USE LARGE AMOUNTS OF PROCESS WATER INCLUDE STEEL, CHEMICAL, AND FOOD PROCESSORS.

SANITARY OR SERVICE WATER IS POTABLE WATER. IT IS USUALLY PURCHASED BY INDUSTRIES. THE COMBINATION OF COOLING, PROCESS, FIRE, SANITARY, AND OTHER WATER SYSTEMS IN INDUSTRIAL PLANTS ARE OFTEN EXTREMELY COMPLEX.

THE IMPORTANCE OF WATER QUALITY FROM AN INDUSTRIAL STANDPOINT

MANY OF THE SUBSTANCES WHICH ARE PRESENT IN WATER, WHETHER THEY ARE THERE NATURALLY OR ARE INTRODUCED BY MAN, CAUSE CONSIDERABLE DIFFICULTY TO THE INDUSTRIAL USER. FOR EXAMPLE, FEEDWATER FOR HIGH-PRESSURE BOILERS, PROCESS WATER FOR DYEING AND WASHING, AND WATER USED IN THE FOOD-PROCESSING AND CHEMICAL INDUSTRIES SHOULD BE VERY LOW IN DISSOLVED SALTS. IF THIS IS NOT THE CASE WITH FEEDWATERS, CONSIDERABLE EXPENSE IS INVOLVED TO REMOVE THESE SALTS BY SUCH PROCESSES AS ION EXCHANGE, DISTILLATION, OR REVERSE OSMOSIS.

THE TWO PRINCIPLE PROBLEMS CREATED BY "IMPURE" WATER FOR INDUSTRIAL USERS ARE SCALE FORMATION (THE PRECIPITATION AND DEPOSITION OF SOLIDS ON PIPE AND VESSEL SURFACES) AND CORROSION (THE EROSION OF PIPE AND VESSEL SURFACES DUE TO CHEMICAL ATTACK OR ABRASION). SCALE ORMATION IS USUALLY ASSOCIATED WITH HARDNESS IN WATER--I.E., THE PRESENCE OF HIGH CONCENTRATIONS OF CALCIUM AND MAGNESIUM SALTS. THE HEATING OF WATER, AS IS THE CASE WITH COOLING WATER, CAUSES PRECIPITATION AND DEPOSITION OF THESE SALTS. SCALE FORMATION IS ALSO ENHANCED WITH ALKALINE CONDITIONS. REMOVING THE SALTS CAN BE EXPENSIVE AND DIFFICULT. THEREFORE, USERS HAVE OFTEN TURNED TO ADDING CHEMICAL SCALE-INHIBITORS SUCH AS CERTAIN PHOSPHATES AND CHROMATES. THE PRESENCE OF THESE CHEMICALS, HOWEVER, CAN BECOME A PROBLEM IN WASTEWATER DISCHARGES.

CORROSION IN WATER SYSTEMS IS OFTEN ENHANCED BY A NUMBER OF FACTORS, INCLUDING VERY LOW pH OR HIGH pH; THE PRESENCE OF HIGH DISSOLVED SOLIDS AND/OR HIGH DISSOLVED OXYGEN; AND ELEVATED WATER TEMPERATURES. CORROSIVE WATERS ARE ALSO OFTEN TREATED BY CHEMICAL ADDITIONS TO INHIBIT THE CORROSION ACTION.

A LIST OF SOME COMMON IMPURITIES PRESENT IN WATER--INCLUDING THE DIFFICULTIES THEY CAUSE AND THE MEANS OF TREATMENT WHICH CAN BE USED FOR THEIR REMOVAL--IS GIVEN IN TABLE II.

TABLE II. PROBLEM WATER IMPURITIES FOR INDUSTRY (Betz Handbook, 1976)

Constituent	Chemical Formula	Difficulties Caused	Means of Treatment
TURBIDITY	None-expressed in analysis as units.	Imparts unsightly appearance to water. Deposits in water lines, process equipment, etc. interfere with most process uses.	Coagulation, settling and filtration.
COLOR	None-expressed in analysis as units.	May cause foaming in boilers. Hinders precipitation methods such as iron removal and softening. Can stain product in process use.	Coagulation and filtration. Chlorination. Adsorption by activated carbon.
HARDNESS	Calcium and magnesium salts expressed as $CaCO_3$.	Chief source of scale in heat exchange equipment, boilers, pipe lines, etc. Forms curds with soap, interferes with dyeing, etc.	Softening. Demineralization. Internal boiler water treatment. Surface-active agents.
ALKALINITY	Bicarbonate (HCO_3), carbonate (CO_3), and hydrate (OH), expressed as $CaCO_3$.	Foaming and carryover of solids, with steam. Embrittlement of boiler steel. Bicarbonate and carbonate produce CO_2 in steam, a source of corrosion in condensate lines.	Lime and lime-soda softening. Acid treatment. Hydrogen zeolite softening. Demineralization. Dealkalization by anion exchange.
FREE MINERAL ACID	H_2SO_4, HCI, etc. expressed as C_aCO_3.	Corrosion.	Neutralization with alkalies.
CARBON DIOXIDE	CO_2	Corrosion in water lines and particularly steam and condensate lines.	Aeration. Deaeration. Neutralization with alkalies.
pH	Hydrogen ion concentration defined as: $pH = \log \frac{1}{(H+)}$	pH varies according to acidic or alkaline solids in water. Most natural waters have a pH of 6.0-8.0.	pH can be increased by alkalies and decreased by acids.
SULFATE	(SO_4)	Adds to solids content of water, but in itself is not usually significant. Combines with calcium to form calcium sulfate scale.	Demineralization.
CHLORIDE	Cl	Adds to solids content and increases corrosive character of water.	Demineralization.
NITRATE	(NO_3)	Adds to solids content, but is not usually significant industrially. High concentrations cause methemoglobinemia in infants. Useful for control of boiler metal embrittlement.	Demineralization.
FLUORIDE	F	Cause of mottled enamel in teeth. Also used for control of dental decay. Not usually significant industrially.	Adsorption with magnesium, hydroxide, calcium phosphate, or bone black. Alum coagulation.
SILICA	SiO_2	Scale in boilers and cooling water systems. Insoluble turbine blade deposits due to silica vaporization.	Hot process removal with magnesium salts. Adsorption by highly basic anion exchange resins, in conjunction with demineralization.
IRON	Fe^{++}(ferrous) Fe^{+++}(ferric)	Discolors water on precipitation. Source of deposits in water lines, boilers, etc. Interferes with dyeing, tanning, papermaking, etc.	Aeration. Coagulation and filtration. Lime softening. Cation exchange. Contact filtration. Surface-active agents for iron retention.
MANGANESE	Mn^{++}	Same as iron.	Same as iron.
OXYGEN	O_2	Corrosion of water lines, heat exchange equipment, boilers, return lines, etc.	Deaeration. Sodium sulfite. Corrosion inhibitors.

HYDROGEN SULFIDE	H_2S	Cause of "rotten egg" odor. Corrosion.	Aeration. Chlorination. Highly basic anion exchange.
AMMONIA	NH_3	Corrosion of copper and zinc alloys by formation of complex soluble ion.	Cation exchange with hydrogen zeolite. Chlorination. Deaeration.
DISSOLVED SOLIDS	None	"Dissolved Solids" is measure of total amount of dissolved matter, determined by evaporation. High concentrations of dissolved solids are objectionable because of process interference and as a cause of foaming in boilers.	Various softening process, such as lime softening and cation exchange by hydrogen, zeolite, will reduce dissolved solids. Demineralization.
SUSPENDED SOLIDS	None	"Suspended Solids" is the measure of undissolved matter, determined gravimetrically. Suspended solids cause deposits in heat exchange equipment, boilers, water lines, etc.	Subsidence. Filtration, usually preceded by coagulation and settling.
TOTAL SOLIDS	None	"Total Solids" is the sum of dissolved and suspended solids, determined gravimetrically.	See "Dissolved Solids" and "Suspended Solids".

INDUSTRIAL IMPACT ON LAKE MICHIGAN WATER QUALITY

The Great Lakes Water Quality Board in its Sixth Annual Report to the International Joint Commission (IJC) on Great Lakes water quality, July, 1978, has outlined water quality problem areas for the Great Lakes (IJC, 1977). While water quality in Lake Michigan is generally improving, the Board cited four specific problem areas where field measurements show degraded water quality. Whereas many dischargers have complied with effluent limitations, the problem still exists due, in part, "to residual effects of certain substances that remain long after a discharge is eliminated or because remedial programs are not adequate." The Lake Michigan problem areas are Green Bay, Milwaukee Harbor, Waukegan Harbor, and Indiana Harbor (Figure 1). Dischargers in these problem areas are given in Table III.

The loadings attributable to each point source discharge are given in Appendix 3 of the Annual Report (IJC, 1977). It should be noted that the list of significant dischargers is based primarily on the volume of the discharge, not on the quality or load of pollutant discharged, although some small dischargers with heavy loadings are included. The list indicates sources discharging into Lake Michigan's problem areas. Again it is important to note that "these sources are not necessarily contributors to water quality degradation." Many of the sources meet or better their permit requirements, or if they have not, the problem is often minor.

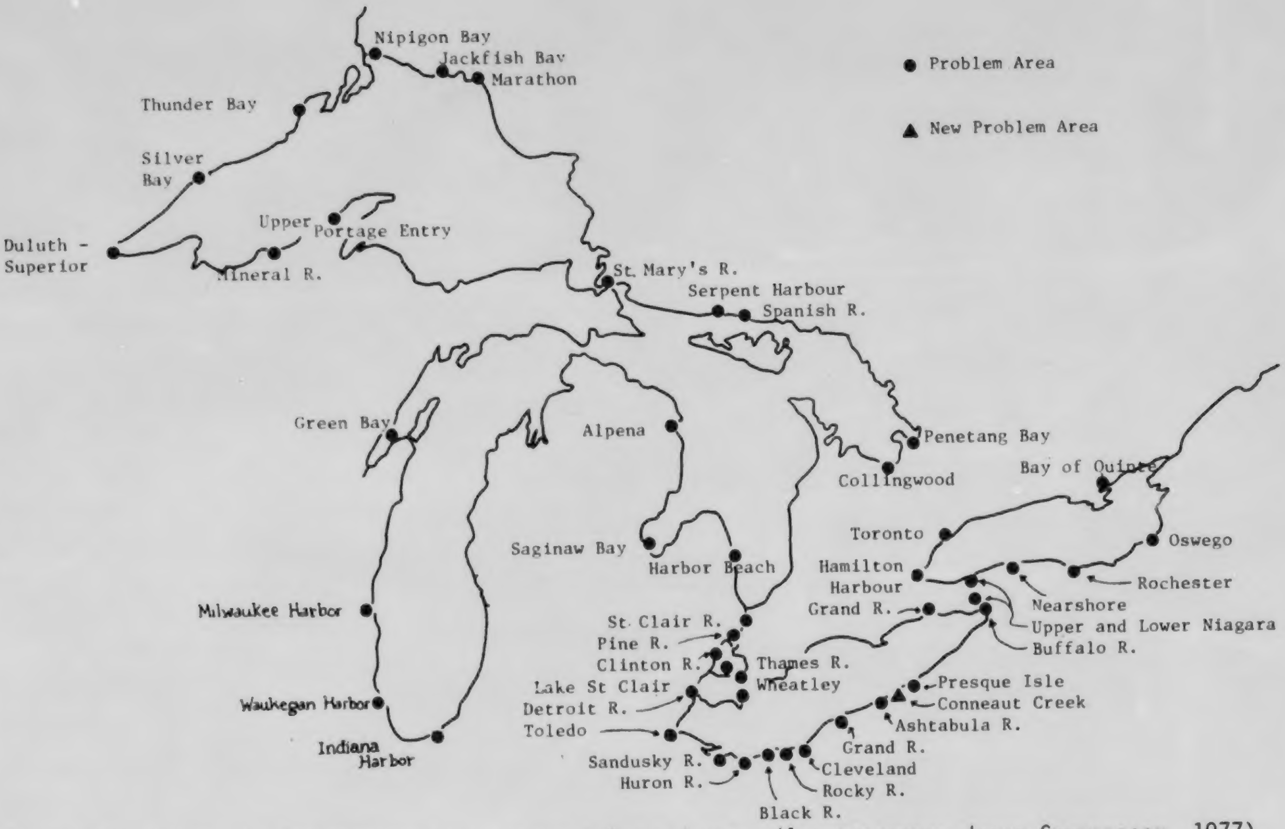

● Problem Area
▲ New Problem Area
Nipigon Bay
Jackfish Bay
Marathon
Thunder Bay
Silver Bay
Duluth - Superior
Upper Portage Entry
Mineral R.
St. Mary's R.
Serpent Harbour
Spanish R.
Green Bay
Alpena
Penetang Bay
Collingwood
Bay of Quinte
Toronto
Oswego
Saginaw Bay
Harbor Beach
Hamilton Harbour
Rochester
Nearshore
Milwaukee Harbor
Grand R.
Upper and Lower Niagara
Buffalo R.
St. Clair R.
Pine R.
Clinton R.
Thames R.
Wheatley
Lake St Clair
Presque Isle
Conneaut Creek
Detroit R.
Waukegan Harbor
Toledo
Ashtabula R.
Indiana Harbor
Grand R.
Sandusky R.
Cleveland
Huron R.
Rocky R.
Black R.

Figure 1. Water quality problem areas for the Great Lakes (International Joint Commission, 1977).

Table III. LAKE MICHIGAN PROBLEM AREAS AND DISCHARGERS

LAKE BASIN/ JURISDICTION	PROBLEM AREAS	DISCHARGERS
MICHIGAN		
Wisconsin	Green Bay	*Wisconsin Public Service *Wisconsin Tissue Mills *Nicolet Paper Corp. *Riverside Paper Co. *Midtec Paper Corp. *Hammermill Paper Co. *Kimberly Clark Corp. (Lakeview Mill) *Kimberly Clark Corp. (Neenah) *Consolidated Paper *Appleton Papers *American Can Co. *Heart of the Valley (Metro), STP *Oshkosh, STP *Ripon, STP *Fort Howard Paper *DePere, STP *Neenah-Menasha Sewage Commission

TABLE III. CONT'D.

LAKE BASIN/ JURISDICTION	PROBLEM AREAS	DISCHARGERS
		*Green Bay (Metro), STP *Menasha Tn. S.D. #4 (East) *Menasha Tn. S.D. #4 (West) *Appleton, STP Proctor and Gamble Green Bay Packaging Inc. Shawano Paper Shawano Lake Sanitary District #1 Fond du Lac, STP Berlin, STP
	Milwaukee Harbor	*Combined Sewer Overflow (Milwaukee) Wisconsin Electric Power Co (Lakeside Plant) Wisconsin Electric Power Co. (Commerce Plant) Cedarburg, STP West Bend, STP Milwaukee (Metro) Sewerage Commission (Jones Island Plant) Menomonee Falls, STP
Illinois	Waukegan Harbor	*Outboard Marine
Indiana	Indiana Harbor Canal	*East Chicago, STP *Gary Sanitary District *Hammond, STP *Energy Co-op *Youngstown Sheet and Tube *American Oil Co. *U.S. Steel, Gary *Inland Steel Union Carbide American Maize DuPont
HURON		
Michigan	Alpena-Thunder Bay	*Abitibi Corp. Alpena, WWTP Fletcher Paper Co.
	Saginaw Bay	*Alma, WWTP *Bay City, WWTP *Bridgeport Twp., WWTP *Buena Vista Twp., WWTP *Dow Chemical Co. (Bay City) *Dow Chemical Co. (Midland) *Flint, WWTP *Flushing, WWTP *Midland, WWTP *Monitor Sugar Co. *Mt. Pleasant, WWTP *Owosso, WWTP *Saginaw Twp., WWTP *Velsicol Chemical Corp. *Combined Sewer Overflow Consumers Power Co. General Motors Corp. (Bay City) General Motors Corp. (Flint) General Motors Corp. (Saginaw) Genesee County District #2, WWTP

*Indicates that discharger is contributing to water quality violation(s) within the problem area identified by the Surveillance Subcommittee. Such dischargers may be in compliance with jurisdictional effluent limits.

A DISCUSSION OF LAKE MICHIGAN'S PROBLEM AREAS HAS BEEN EXCERPTED FROM THE 1975 IJC REPORT AND IS GIVEN BELOW.

> "There are four problem areas in Lake Michigan Basin. Two areas previously identified, the mouths of Escanaba and Manistique rivers, have been deleted from the list due to lack of evidence of water degradation in the boundary waters. Green Bay, Milwaukee Harbor and Indiana Harbor remain. One new problem area, Waukegan Harbor, has been added. The problem there is the PCB contamination of harbor sediments due to discharges from Outboard Marine Company. The State of Illinois and the US EPA have taken enforcement actions against the discharger. There has been no change in status in Milwaukee Harbor. The area continues to have water quality problems caused by storm and combined sewer overflow.
>
> The water quality problem in Green Bay can be attributed principally to the large number of municipal and industrial dischargers along the Fox River in Wisconsin. Several municipalities have improved their effluent quality considerably, namely, Appleton, DePere and Neenah-Menasha. On the industrial side, there have been no significant changes in remedial program status for most of the paper mills along the Fox River. One discharger, Bergstrom Paper in Neenah is presently being sued by the State of Wisconsin for non-compliance with its NPDES permit conditions.
>
> Water quality degradation in the Indiana Harbor and Ship Canal is caused mainly by steel mills and several major municipal dischargers. U.S. Steel in Gary continues with litigation on its permit. Five major remedial programs at this plant remain to be completed. The Gary Sewage Treatment Plant is not in compliance with its permit requirements due to difficulties with plant operation and management. Its interim phosphorus removal facility is inadequate. Enforcement actions have been taken by US EPA."

IT MUST BE EMPHASIZED THAT THE INDUSTRIAL IMPACE ON LAKE MICHIGAN WATER QUALITY IS NOT ONLY A FUNCTION OF POINT SOURCE DISCHARGE. WHILE THERE IS SOME SMALL IMPACT FROM NON-POINT SOURCES--THAT IS, RUNOFF AND LEACHING OF POLLUTANTS--A MAJOR SOURCE OF WATER POLLUTION IS FROM ATMOSPHERIC LOADING OF POLLUTANTS TO STREAMS AND LAKES.

RECENT STUDIES INDICATE THAT AIRBORNE PHOSPHORUS LOADINGS EXCEED 4,400 TONS/YEAR FOR ALL FIVE GREAT LAKES. AN ARGONNE LABORATORY REPORT ESTIMATES THAT IN LAKE MICHIGAN "ATMOSPHERIC INPUTS OF PHOSPHORUS, NITROGEN, AND LEAD ACCOUNTS (SIC) FOR AT LEAST 20% OF ALL INPUTS TO THE LAKE FOR THESE ELEMENTS." OTHER SUBSTANCES WHICH ENTER THE LAKE IN SIZEABLE QUANTITIES VIA AIRBORNE DEPOSITS ARE COPPER, SELENIUM, SULFUR, ZINC, VANADIUM, NICKEL AND PCBs (IJC, 1977).

WATER POLLUTION REGULATIONS -- THEIR IMPACT ON INDUSTRY

THE BASIS FOR REGULATION

HOW DID WE GET WHERE WE ARE? WELL INTO THE 20TH CENTURY THE WATER SUPPLY IN THE UNITED STATES (ESPECIALLY THE EAST AND MIDWEST) WAS EASILY SUFFICIENT TO SUPPLY INDUSTRIAL AS WELL AS OTHER NEEDS. THE LAKES AND STREAMS WHICH RECEIVED INDUSTRIAL AS WELL AS MUNICI-

PAL AND AGRICULTURAL WASTES WERE OF SUFFICIENT CAPACITY TO RECEIVE THOSE WASTES AND ASSIMILATE THEM, WHILE AT THE SAME TIME MAINTAINING A REASONABLY HIGH WATER QUALITY. SIGNS OF TROUBLE, HOWEVER, WERE UNMISTAKEABLE IN SOME LAKES AND RIVERS SERVING POPULATION CENTERS AND HIGH CONCENTRATIONS OF HEAVY INDUSTRY.

BECAUSE THE INITIAL EFFECTS OF WATER POLLUTION ARE OFTEN GRADUAL AND SUBTLE, THE PROBLEM WAS NOT WIDELY NOTED NOR CLEARLY UNDERSTOOD. INDUSTRIAL GROWTH WAS THE PRIDE OF THE NATION, A CAUSE "CELEBRE", AND FEW QUESTIONED THE UGLY BY-PRODUCTS OF THE SOURCE OF AMERICAN PROSPERITY AND WELL-BEING. IT IS IMPORTANT TO UNDERSTAND THAT THE "RIGHT" TO DISCHARGE WASTES INTO PUBLIC WATERWAYS BECAME AN ACCEPTED AND PREVAILING AXIOM. WHEN THE ALARMS WERE EVENTUALLY SOUNDED, INDUSTRIES WERE UNDERSTANDABLY NOT THE FIRST TO JUMP ON THE "CLEAN-UP" BANDWAGON. THE COST TO REPAIR THE SITUATION WOULD BE STAGGERING.

WATER QUALITY REGULATIONS

PRIOR TO 1972, THE VARIOUS STATES HAD, IN EFFECT, REGULATIONS WHICH WERE PRIMARILY "WATER QUALITY STANDARDS"; THAT IS, STANDARDS WHICH SET LIMITS ON THE PERMISSIBLE CONCENTRATIONS OF VARIOUS POLLUTANTS IN SPECIFIC BODIES OF WATER SUCH AS LAKES, RIVERS, AND STREAMS. THESE REGULATIONS, AS THEY EXISTED, WERE OFTEN NOT CONSISTENT OR UNIFORM ACROSS THE NATION. ALSO, THEY WERE DIFFICULT, IF NOT IMPOSSIBLE, TO ENFORCE, AND THUS PROVED TO BE INEFFECTIVE IN CONTROLLING WATER POLLUTION. THIS SITUATION THEN SET THE STAGE FOR THE PASSAGE OF THE MOST IMPORTANT PIECE OF WATER POLLUTION CONTROL LEGISLATION IN THE NATION'S HISTORY.

THE FEDERAL WATER POLLUTION CONTROL ACT

THIS SECTION DEALS WITH THE FEDERAL WATER POLLUTION CONTROL ACT OF 1972 AND ITS WIDESPREAD IMPACT ON INDUSTRY. A DISCUSSION OF THE BROAD AUTHORITY GIVEN TO THE EPA IS FOLLOWED BY OTHER SUBSECTIONS ON THE GENERATION OF EFFLUENT GUIDELINES, THE IMPACT ON AND COMPLEMENTARY NATURE OF STATE WATER QUALITY REGULATIONS, THE NPDES PERMIT SYSTEM, TOXIC AND HAZARDOUS SUBSTANCE GUIDELINES, SPILL-PREVENTION REGULATIONS, ENFORCEMENT PROCEDURES, AND FINALLY HIGHLIGHTS OF THE 1977 AMENDMENTS TO THE ACT.

EPA AUTHORIZATIONS -- IN 1972 CONGRESS PASSED THE FEDERAL WATER POLLUTION CONTROL ACT (PUBLIC LAW 92-500-NOW CALLED, ALONG WITH ITS AMENDMENTS, THE CLEAN WATER ACT) WHOSE STATED GOAL WAS "TO RESTORE AND MAINTAIN THE CHEMICAL, PHYSICAL, AND BIOLOGICAL INTEGRITY OF THE NATION'S WATERS."

THE 1972 LAW SHIFTED THE EMPHASIS FROM WATER QUALITY STANDARDS TO A PERMIT SYSTEM WHEREIN DISCHARGERS HAD TO LIMIT THEIR POLLUTANTS IN ACCORDANCE WITH SPECIFIC EPA-DETERMINED EFFLUENT LIMITATIONS. ATTAINMENT OF WATER QUALITY STANDARDS REMAINED THE OBJECTIVE, BUT THIS OBJECTIVE WAS TO BE REACHED BY INSURING COMPLIANCE WITH SPECIFIC "POINT SOURCE" EFFLUENT LIMITATIONS. THE MAJOR GOALS OF THE CLEAN WATER ACT WERE AS FOLLOWS:

1. National goal of fishable and swimable water by July 1, 1983.
2. National goal of zero pollutant discharge by 1985.

The Act authorized the EPA to regulate the discharge of pollutants according to this strict timetable and to promulgate effluent limitation guidelines which establish the maximum permissible effluent discharges into waterways by industries and others. It also authorized the EPA to approve water quality standards which individual states would adopt. A crucial stipulation of the Act authorized the EPA and EPA-approved states to issue discharge permits to industrial and municipal facilities.

The Act relies principally upon technology-based effluent standards, i.e., achievement of a given level of wastewater treatment--and upon a permit system to enforce the standards. The EPA was also given authority to regulate thermal pollution, the discharge of toxic substances, and spills of oil and hazardous substances into national waterways.

A brief look at EPA effluent guidelines and water quality standards as they have been set up to implement this aspect of the Act follows.

EPA Effluent Guidelines -- The generation of effluent guidelines for point sources which are, in effect, performance standards took the form of a two-stage program for existing water pollution sources and another stage for new sources.

Stage 1 -- Best Practicable Technology (BPT)

BPT was considered to be the minimum of compliance under the law and was to be achieved by July 1, 1977. Approximately 85 percent of industrial dischargers met this deadline. BPT represents the average of the best existing performance by well-operated wastewater treatment plants within each industrial category or subcategory. The EPA surveyed the available technology in each category. They hired contractors to visit existing plants and study their waste treatment facilities. The best facilities often became the norm or BPT. Where the existing treatment measures were found to be generally inadequate, the EPA set more stringent standards where technology was reasonably available. It is important to note that BPT, the first stage, emphasized treatment of discharges to attain compliance; however, many well-run plants were capable of meeting these standards by simply altering their processes somewhat or tightening up on leaks, etc. The development process for effluent limitation guidelines and standards is given in Figure 2. (Council on Wage and Price Stability, 1976).

Stage 2 -- Best Available Technology (BAT)

More stringent effluent guidelines based on the "best available technology economically achieveable" (BAT) were developed to apply to existing point sources no later than July 1, 1983. This compliance was subsequently moved back one year. These limitations were designed to effect two principle objectives:

1. Achievement of the greatest amount of uniformity among similar industries and municipalities, and
2. Reduction of pollutant discharge so that reasonable progress can be made to achieve a 1985 national goal of "no discharge".

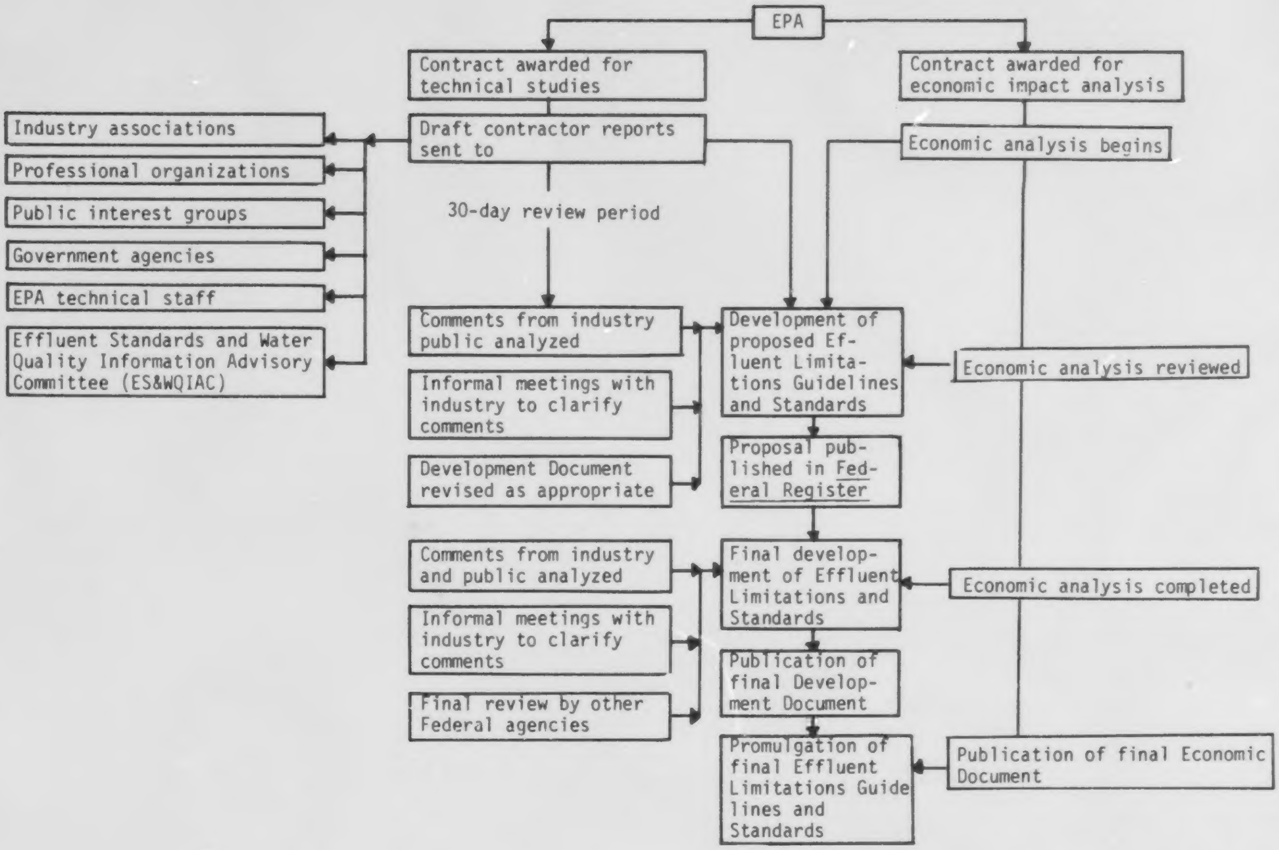

EPA
Contract awarded for technical studies
Contract awarded for economic impact analysis
Industry associations
Professional organizations
Public interest groups
Government agencies
EPA technical staff
Effluent Standards and Water Quality Information Advisory Committee (ES&WQIAC)
Draft contractor reports sent to
30-day review period
Economic analysis begins
Comments from industry public analyzed
Informal meetings with industry to clarify comments
Development Document revised as appropriate
Development of proposed Effluent Limitations Guidelines and Standards
Economic analysis reviewed
Proposal published in Federal Register
Comments from industry and public analyzed
Informal meetings with industry to clarify comments
Final review by other Federal agencies
Final development of Effluent Limitations and Standards
Economic analysis completed
Publication of final Development Document
Promulgation of final Effluent Limitations Guidelines and Standards
Publication of final Economic Document

FIGURE 2. DEVELOPMENT PROCESS FOR EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS (COUNCIL ON WAGE AND PRICE STABILITY, 1976).

STAGE 3 -- NEW PERFORMANCE STANDARDS

A third set of effluent guidelines which closely resemble Stage 2 guidelines were developed to apply to new sources, the construction of which was commenced after the publication of the proposed standards of performance.

For each stage, the regulations specify the maximum amount of pollutant per unit of production which can be discharged in any one day and the maximum average amount over a 30-day period.

STATE WATER QUALITY STANDARDS -- AFTER THE PASSAGE OF THE CLEAN WATER ACT, THE STATE WATER QUALITY REGULATIONS WERE SUBJECT TO EPA APPROVAL. AS MENTIONED ABOVE, WATER QUALITY STANDARDS ARE GENERALLY STATED IN TERMS OF CONCENTRATIONS ALLOWABLE IN PARTICULAR BODIES OF WATER -- E.G., MILLIGRAMS PER LITER OF SUSPENDED SOLIDS, AMMONIA NITROGEN, OR CYANIDE.

A key provision of the Act is that a state could set an alternate set of effluent limitations where the EPA's effluent limitations would not achieve the state water quality standards. This is the case with permits issued to companies on the Grand Calumet River or the Indiana Harbor Ship Canal in northern Indiana. A load allocation study run on these streams provided the basis for stricter effluent standards than those developed by the EPA. Figure 3 (Council on Wage and Price Stability, 1972) indicates the development process of permit requirements by the EPA and the state. An example of a Water Quality Standard is the case of Indiana Regulation No. SPC-4R citing minimum conditions applicable to waters of Lake Michigan and Harbor areas.

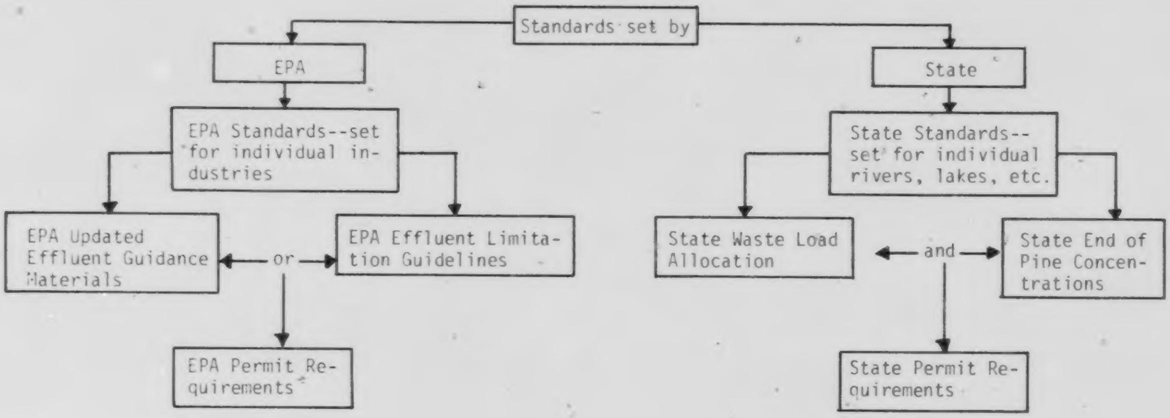

Standards set by
EPA
State
EPA Standards--set for individual industries
State Standards--set for individual rivers, lakes, etc.
EPA Updated Effluent Guidance Materials
or
EPA Effluent Limitation Guidelines
State Waste Load Allocation
and
State End of Pipe Concentrations
EPA Permit Requirements
State Permit Requirements

Figure 3. Effluent Discharge Standards Under FWPCA

NPDES Permits -- The Clean Water Act established the National Pollutant Discharge Elimination System (NPDES) which required all point source dischargers to obtain discharge permits by December 31, 1974. These permits could be issued by the EPA or an EPA-approved state and are normally good for five years. The initial permits incorporated BPT and translated the pound of pollutant per unit of production into end-of-the-pipe concentrations or pounds/day limits.

Dischargers whose discharge of pollutants exceeded their permits generally had to agree to a compliance schedule which involved the installation of improved wastewater treatment facilities. The issuance of NPDES permits under EPA and state standards is presented in Figure 4. Examples of an NPDES permit issued to a company are given in Appendix 1. Note that some standards are wasteload limits (pounds/day) plus some "end-of-the-pipe"

CONCENTRATION LIMITS (MG/L). ALSO, PERMITS MAY INCLUDE MONITORING REQUIREMENTS AND MAY SPECIFY AMONG OTHER THINGS:

1. COMPLIANCE SCHEDULES.
2. SLUDGE-DISPOSAL CONDITIONS.
3. REQUIRED INTAKE IMPACT STUDIES ON FISH AND OTHER AQUATIC ORGANISMS.
4. THERMAL DISCHARGE REQUIREMENTS.

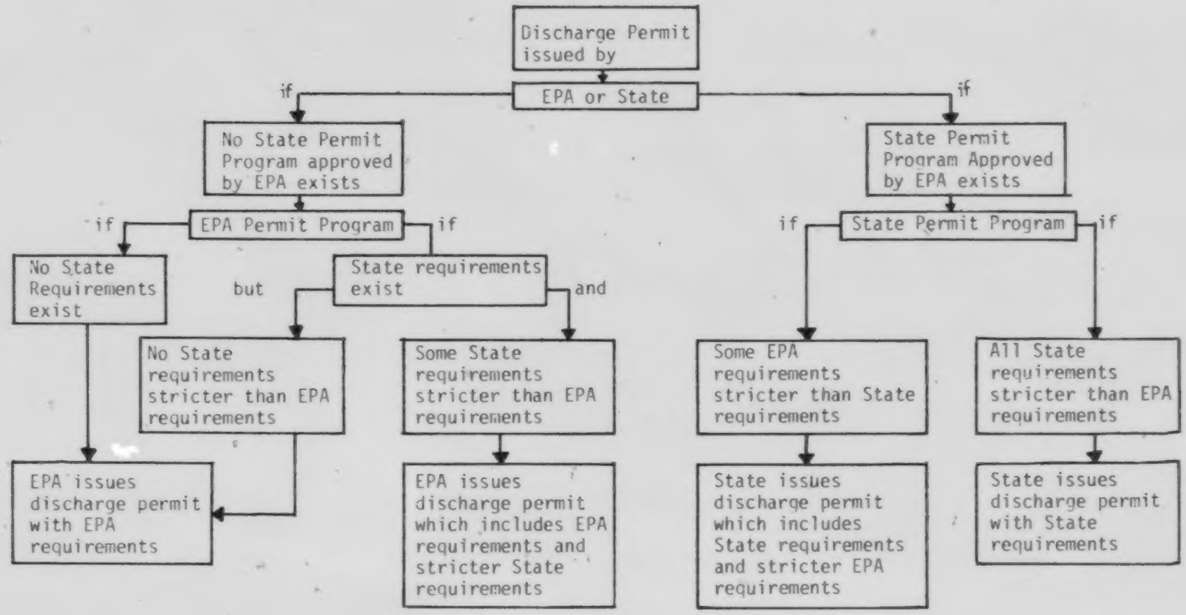

Discharge Permit issued by
EPA or State
if
if
No State Permit Program approved by EPA exists
State Permit Program Approved by EPA exists
EPA Permit Program
State Permit Program
if
if
if
if
No State Requirements exist
State requirements exist
but
and
No State requirements stricter than EPA requirements
Some State requirements stricter than EPA requirements
Some EPA requirements stricter than State requirements
All State requirements stricter than EPA requirements
EPA issues discharge permit with EPA requirements
EPA issues discharge permit which includes EPA requirements and stricter State requirements
State issues discharge permit which includes State requirements and stricter EPA requirements
State issues discharge permit with State requirements

FIGURE 4. ISSUANCE OF NPDES PERMITS UNDER EPA AND STATE STANDARDS

TOXIC AND HAZARDOUS SUBSTANCE GUIDELINES -- THE RAPID PROLIFERATION IN RECENT YEARS OF PESTICIDES, INDUSTRIAL CHEMICALS, AND OTHER TOCIS SUBSTANCES HAS BECOME A MAJOR POLLUTION PROBLEM. CHEMICALS SUCH AS DDT, MIREX, AND PCB SLIP THROUGH TRADITIONAL BIOLOGICAL TREATMENT PROCESSES. MORE THAN 700 SYNTHETIC ORGANICS HAVE ALREADY BEEN IDENTIFIED IN WATER, AND NO ONE REALLY KNOWS AT WHAT CONCENTRATION LEVELS THEY BECOME HARMFUL TO AQUATIC ORGANISMS AND HUMANS. THEREFORE, CONGRESS HAS BEEN AIMING AT ZERO DISCHARGE OF SUCH TOXICS. RATHER THAN "END-OF-THE-PIPE" TREATMENT, REGULATIONS ARE INCREASINGLY STRESSING PROCESS CHANGES, RECYCLING, AND RECOVERY OF BY-PRODUCTS.

Section 307 of the Clean Water Act provides procedures for regulating the discharge of toxic substances. The 1977 amendments to the Act give the toxic control effort added thurst. The EPA has begun work to develop BAT standards to control 129 "priority" pollutants believed to have toxic characteristics. If further study finds any of these chemicals not toxic, they may be deleted from the list. Conversely, newly-found toxics may be added to the list.

The EPA must promulgate BAT effluent guideline regulations covering 21 industry categories by July 1, 1980. As regulations are promulgated, they become part of a company's NPDES permit, and compliance is required as soon as possible, but not later than three years from the date of promulgation.

Regulation of Spills of Oil and Hazardous Substances -- Section 311 of the Act gives the EPA the authority to issue regulations dealing with spills of oil and hazardous substances into the nation's waterways. The EPA issued regulations for 271 chemicals on March 13, 1978, covering reporting, liability, and a cleanup scheme for spills or discharges into navigable waters. Facilities which have discharged oil or could reasonably be expected to discharge oil in harmful quantities are required to prepare and implement a spill prevention control and countermeasure plan (SPCC).

Pretreatment Guidelines -- The Act provided the EPA with authority to issue pretreatment standards for industries covering the introduction of pollutants into publicly-owned treatment works (POTW's) which are not susceptible to treatment by the POTW. Compliance with pretreatment standards must be within three years of the date of promulgation.

Enforcement of the Act -- Enforcement of the Act can proceed by either the EPA, state officials, or citizen suits. The Act provides for criminal and civil penalties for violations. In general, if a firm or municipality is complying with its NPDES permit, it is deemed in compliance with the provisions of the Act.

The Amendments of 1977 -- The original Clean Water Act of 1972 provided a mechanism for "mid-course" corrections recognizing that its provisions were particularly far-reaching.

Since 1972, U.S. industry has made considerable progress in water pollution. About 80% of the nation's industries met the July 1, 1977 deadline to install best practicable technology (BPT). The cost, however, was very high. The petroleum industry spent about $4.4 billion, and the steel industry $2 billion to reduce discharges.

Hence, industry argued for postponement of the 1983 BAT deadline citing the cost of going from BPT to BAT at $60 billion, and yet projecting the improvements as only marginal. Industry wanted Congress to get tough on municipalities and federal facilities, only one-third of whom had met the 1977 requirement for secondary treatment.

The result was that in the 1977 Amendments to the Act Congress made the following changes:

1. Toxic Pollutants -- EPA is required to promulgate BAT effluent guideline regulations covering 21 basic industries and 65 toxic pollutant classes by July 1, 1980.
2. Conventional Pollutants -- EPA must publish a list of "conventional" pollutants including BOD, suspended solids, fecal coliform, and pH. The standard for these pollutants is no longer BAT, but Best Conventional Technology (BCT), a technology somewhere between BPT required for July 1, 1977, and BAT. The effluent guidelines for industries must be published by July 1, 1980.
3. Other Pollutants -- EPA must also promulgate effluent guidelines for pollutants not in the toxic nor conventional categories. The compliance date for these is established as three years after promulgation, but not later than July 1, 1987.
4. EPA must publish pretreatment requirements for industries discharging into municipal treatment plants so that the combined treatment (pretreatment, and municipal treatment) for toxic substances is at least at the BAT level.
5. EPA can require of industry best management practices to control on-site runoff, spills, sludge disposal, leaching, etc.

A summary of current standards in the 1972 Clean Water Act and the 1977 Amendments as they affect industry and publicly-owned treatment plants is given in Table IV (see p.354).

The processes necessary to attain a given level of treatment or pollutant removal are substantially the same for industry as for publicly owned wastewater treatment plants. Since only the pollutant mix will vary, the reader is referred to the chapter on water supply and wastewater treatment for a discussion of the general processes common to all wastewater treatment facilities. The remaining text directs its attention to problems unique to industrial water quality treatment.

TABLE IV. WATER EFFLUENT STANDARDS

	TYPE OF SOURCE	POLLUTANTS	DATE EFFECTIVE	BY WHOM ESTABLISHED	ENFORCEMENT MECHANISM	SCOPE
Water Quality Standards	Not a "Source" --Rivers, Streams, Lakes, & All Surface Waters	Various	July 1, 1984	States/EPA Approval	Permits/State Programs for Nonpoint Sources	All surface waters except those specifically approved by EPA for less stringent classification.
Best Practicable Control Technology (BPT)	Industry & Major Feedlots (Existing)	Various	July 1, 1977	EPA	Permits (NPDES)	Add-On Treatment Technology--Includes Process Changes
Best Conventional Pollutant Control Technology (BCT)	Industry, Feedlots, & Municipalities	pH, BOD, TSS, Fecal coliform	July 1, 1984	EPA	Permits (PNDES)	Downgraded these pollutants from BAT requirements to something above BPT.
Nonconventional or "Gray Area" (BAT)	Industry	Pollutants not in toxic or conventional categories	July 1, 1984, or as appropriate	EPA	Permits (NPDES)	Can be allowed variances from BAT on economic or environmental grounds.
Best Available Technology Economically	Industry	Toxic	July 1, 1984, or as appropriate for 129 toxics.	EPA	Permits (NPDES)	Unlimited--Any changes needed to prohibit/limit toxics.
Best Management Practices (BMP's)			None	EPA	Permits (NPDES)	Practices to Limit Runoff, Spills, Etc.
Effluent Standards			Up to 1 year after promulgation or as appropriate for added toxics.	EPA	Permits (NPDES)	Unlimited--Any changes needed to prohibit/limit toxics.
Pretreatment Effluent Standards	Industries Introducing Wastes into Publicly-Owned Treatment Plants	Toxic	Within 3 years of promulgation of standards	EPA	Permit	Must remove any pollutants the POTW cannot treat

HOW INDUSTRY TREATS ITS WASTES

THE PROBLEM OF MEETING EFFLUENT LIMITATIONS FOR A WIDE RANGE OF POLLUTANTS HAS NECESSITATED INNOVATIVE SOLUTIONS TO COMPLEX TREATMENT PROBLEMS. THIS SECTION DEALS BRIEFLY WITH, FIRST OF ALL, THE KINDS OF "END OF THE PIPE" TREATMENT WHICH CAN BE UTILIZED TO MEET PERMIT REQUIREMENTS AND, SECONDLY, SOME STRATEGIES THAT ARE USED TO REDUCE THE MAGNITUDE OF THE PROBLEM BY CONCENTRATING ON THE SOURCE. THE LATTER APPROACH RECOGNIZES THAT IT IS OFTEN

MORE ECONOMICAL TO MODIFY OR REDUCE THE CONCENTRATION OF A POLLUTANT AT ITS POINT OF ORIGIN RATHER THAN TREAT IT AT THE "END OF THE PIPE" WHERE DILUTION OR CONFOUNDING WITH OTHER POLLUTANTS MAKES THE PROBLEM MORE COMPLEX AND MORE COSTLY TO SOLVE. TO THIS END, ONCE-THROUGH SYSTEMS WILL BE CONSIDERED AND CONTRASTED TO RECYCLE SYSTEMS, BOTH CLOSED AND OPEN, AND FINALLY, THE FEASIBILITY AND PRACTICALITY OF TOTALLY ZERO DISCHARGE, THE 1985 OBJECTIVE OF THE CLEAN WATER ACT, WILL BE CONSIDERED.

THE KINDS AND AMOUNTS OF WASTES GENERATED BY INDUSTRIES ARE AS VARIED AS THE INDUSTRIES THEMSELVES, HENCE IT IS IMPOSSIBLE TO CHARACTERIZE INDUSTRIAL WASTE AS A TYPICAL MIXTURE OF SUBSTANCES. WHAT MAY BE A PROBLEM POLLUTANT FOR ONE INDUSTRY MAY BE OF NEGLIGIBLE CONCERN TO ANOTHER. IN GENERAL, HOWEVER, THE WATER POLLUTION CONTROL OR TREATMENT PROBLEMS FACED BY INDUSTRY ARE OFTEN SIMILAR TO THOSE OF PUBLICLY OWNED TREATMENT FACILITIES.

INDUSTRIAL WATER QUALITY TREATMENT STRATEGIES

THE ADVENT OF WATER SCARCITY AND STRICTER DISCHARGE LIMITATIONS HAS GREATLY ALTERED INDUSTRIAL WASTEWATER TREATMENT STRATEGIES. WHEREAS THE NORM BEFORE 1970 WAS GENERALLY ONCE-THROUGH, NON-CONTACT COOLING OR ONCE-THROUGH PROCESS WATER SYSTEMS, WHERE ALL WATER WAS DISCHARGED AFTER USE AND WATER TREATMENT WAS OFTEN MINIMAL, THE SHIFT TODAY IS UNMISTAKEABLY TO RECYCLING SYSTEMS WHERE WATER IS TREATED AND RECIRCULATED MANY TIMES, WITH ONLY A SMALL PORTION BLOWN DOWN TO LOCAL WATERWAYS. INDUSTRY IS COMPLYING WITH NPDES PERMIT LIMITATIONS WHICH, IN ESSENCE, REQUIRE RECYCLING, AND MOST OF THESE SYSTEMS ARE ALREADY INSTALLED OR ARE UNDER CONSTRUCTION. THE NEXT STEP, ZERO DISCHARGE, REMAINS A MAJOR BONE OF CONTENTION AS THE EPA WEIGHS THE TECHNICAL FEASIBILITY AND THE ECONOMIC PROS AND CONS OF ELIMINATING ALL POLLUTANT DISCHARGES.

ONCE-THROUGH SYSTEMS: COOLING AND PROCESS WATER -- THE ONCE-THROUGH SYSTEM IS SIMPLY THAT; WATER IS WITHDRAWN FROM A LAKE, RIVER, OR STREAM AND, AFTER ONE PASS THROUGH A COOLING SYSTEM OR CONTACT WITH A PROCESS, IT IS DISCHARGED TO A WATERWAY. IN THE CASE OF COOLING WATER, THE MINERAL CONTENT OF INFLUENT AND EFFLUENT IS ESSENTIALLY THE SAME BECAUSE THERE HAS BEEN NO CONTACT WITH THE INDUSTRIAL PROCESS. LITTLE OR NO EVAPORATION HAS TAKEN PLACE. DISCHARGE TEMPERATURES ARE GENERALLY 5°-30°F ABOVE INFLUENT TEMPERATURES. FOR ONCE-THROUGH PROCESS WATER, HOWEVER, RELATIVELY PURE WATER OFTEN BECOMES CONTAMINATED WITH PROCESS CONTAMINANTS. EVEN THOUGH THIS WATER MAY BE TREATED, ITS DISCHARGE, BECAUSE OF THE LARGE VOLUMES INVOLVED, CAN STILL RESULT IN LARGE LOADINGS OF POLLUTANTS TO THE RECEIVING WATERWAYS.

RECYCLE SYSTEMS -- RECYCLE SYSTEMS TAKE SEVERAL FORMS AND SERVE BOTH THE FUNCTIONS OF NON-CONTACT COOLING AND PROCESS NEEDS. AS WAS MENTIONED EARLIER, COOLING SYSTEMS CAN GIVE RISE TO SERIOUS WATER QUALITY PROBLEMS FOR THE USER. IN OPEN, NON-CONTACT RECYCLE SYSTEMS WHERE COOLING TOWERS ARE USED TO REMOVE PROCESS HEAT, THE EVAPORATION WHICH TAKES

PLACE, OFTEN 2-4%, CAUSES AN INCREASE IN TOTAL DISSOLVED SOLIDS--IN THE FORM OF SALTS, THAT ARE PRESENT IN THE WATER; OFTEN BLOWDOWN OR CONTINUOUS DISCHARGE OF A PORTION OF THE WATER IS REQUIRED (FIGURE 5).

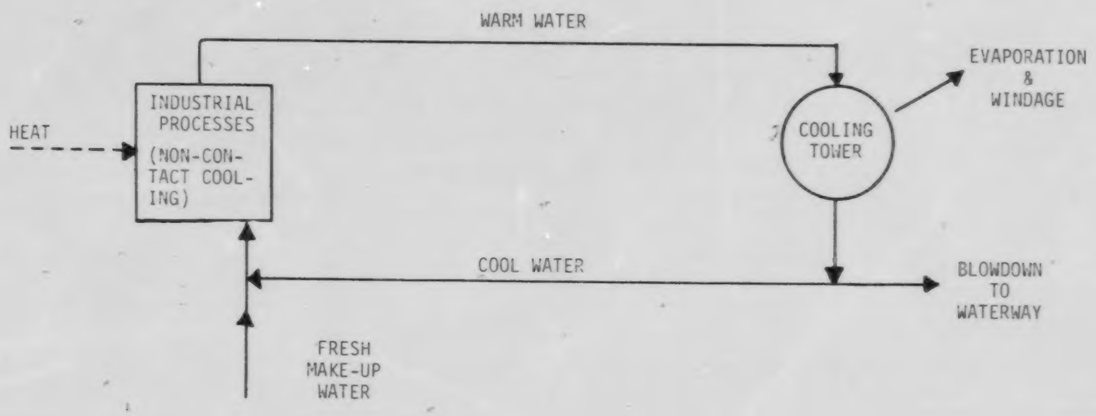

WARM WATER
HEAT
INDUSTRIAL PROCESSES (NON-CONTACT COOLING)
COOLING TOWER
EVAPORATION & WINDAGE
COOL WATER
BLOWDOWN TO WATERWAY
FRESH MAKE-UP WATER

FIGURE 5. OPEN NON-CONTACT COOLING WATER RECYCLE SYSTEM

A CLOSED, NON-CONTACT COOLING WATER SYSTEM IS USED WHERE WATER QUALITY IS CRITICAL TO EQUIPMENT PERFORMANCE. IN ESSENCE, THIS ARRANGEMENT CONSISTS OF TWO COOLING LOOPS, ONE CLOSED RECYCLE, AND ONE EITHER ONCE-THROUGH OR OPEN RECYCLE. THE CLOSED LOOP IS MADE UP OF NEARLY-PURE SOFTENED WATER, AND IS WHOLLY CONTAINED WITHIN A CLOSED PIPING SYSTEM; THEREFORE, THEORETICALLY, NO ADDITION OF FRESH WATER TO IT IS NEEDED (FIGURE 6).

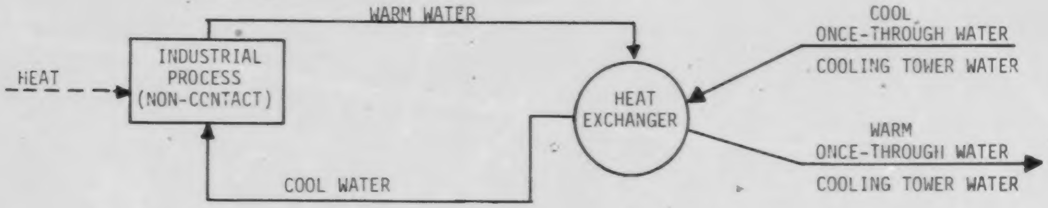

WARM WATER
HEAT
INDUSTRIAL PROCESS (NON-CONTACT)
HEAT EXCHANGER
COOL ONCE-THROUGH WATER
COOLING TOWER WATER
WARM ONCE-THROUGH WATER
COOLING TOWER WATER
COOL WATER

FIGURE 6. CLOSED NON-CONTACT COOLING WATER RECYCLE SYSTEM

Cooling systems have the advantage of greatly reducing the amount of heat which is discharged to a waterway; however, a blowdown of 10-20% is still necessary to reduce the buildup of dissolved solids.

Process recycle systems simply recirculate the contaminated process water after some treatment step or steps back to the process. Normally, some form of advanced waste treatment (AWT) is usually required to maintain water of suitable quality, and a minimum of secondary treatment is always required (Figure 7).

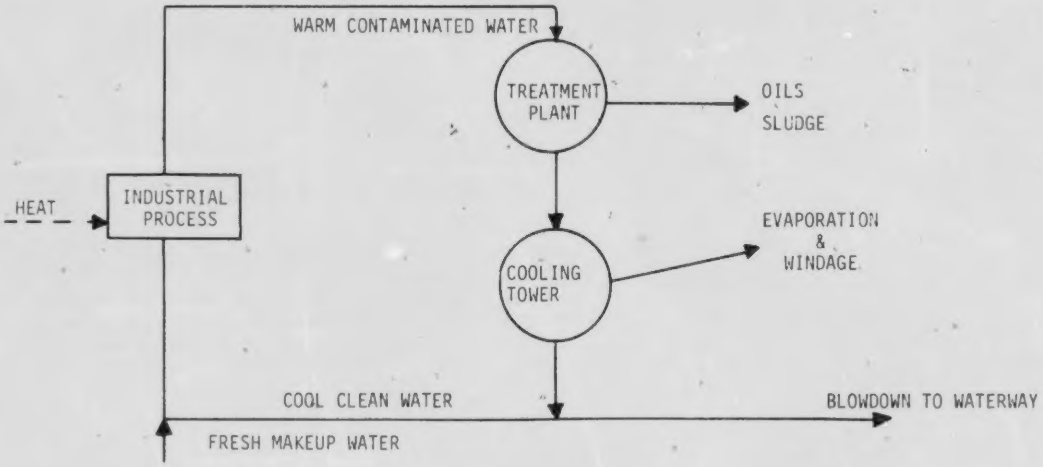


Figure 7. Process Water Recycle System

The advantages of a process water recycle system is that it greatly diminishes the volume of pollutants discharged to the waterway. The blowdown is again necessary to control the buildup of total dissolved solids in the water and thus control scale buildup in interior piping and equipment. Examples of major industrial recycle applications utilizing large quantities of recirculated water are ammonia plant process condensate, chemical plant process condensate, refinery sour water stripper bottoms, paper mill process water, and steel mill wastewater.

Zero Discharge of Pollutants -- The goal or, indeed, the possibility of obtaining zero discharge of pollutants by 1985 is currently being hotly debated in government and in industry. While zero discharge sounds very good in theory, its attainment in practice is seriously affected by other considerations, both technical and economic, and it, in turn, has raised some serious questions regarding resource and economic trade-offs.

Air pollution control regulations have led to pollution control expenditures by industry, which now exceed those for wastewater treatment. Control of air pollution, how-

EVER, HAS A DIRECT BEARING ON WASTEWATER TREATMENT. MANY AIR POLLUTION CONTROL SYSTEMS ARE WET, SUCH AS SCRUBBERS AND WET PRECIPITATORS. THEY HAVE GIVEN RISE TO GREATLY-INCREASED WASTEWATER TREATMENT REQUIREMENTS, AND HAVE INCREASED THE AMOUNT OF WASTE SOLIDS WHICH MUST BE DISPOSED OF IN LANDFILLS OR RECYCLED. RECYCLING IS OFTEN COSTLY AND UNECONOMIC IN TERMS OF CAPITAL AND ENERGY-CONSUMPTION. DRY AIR POLLUTION CONTROL SYSTEMS ALSO GENERATE VAST AMOUNTS OF SOLIDS WHICH FREQUENTLY END UP IN LANDFILLS. THE CURRENT ESTIMATE OF WASTES GENERATED IN THE UNITED STATES WHICH ARE LANDFILLED IS ABOUT 143,000 TONS/DAILY. ALL MATERIALS WHICH ARE LANDFILLED ARE ULTIMATELY A SOURCE OF WATER POLLUTION DUE TO LEACHING OF CONTAINED POLLUTANTS. THUS, CONTAINMENT OF WATER POLLUTION AT THE "END OF A PIPE" CAN OFTEN RESULT IN NONPOINT SOURCE POLLUTION FROM LANDFILL AND FROM DUMPS. CONTAINMENT OF ENVIRONMENTAL POLLUTION DUE TO SOLID AND LIQUID WASTE DISPOSAL GROWS AS THE GENERATION OF THESE WASTES GROWS. A MAJOR EFFORT AT CONTROLLING THIS PROBLEM IS NOW BEING LAUNCHED, LARGELY UNDER THE AUSPICES OF THE RESOURCE CONSERVATION AND RECOVERY ACT OF 1976 (PL 94-580).

ZERO DISCHARGE USUALLY MEANS TOTAL ELIMINATION OF BLOWDOWN STREAMS FROM RECYCLE SYSTEMS SO THAT NO POLLUTANTS ARE DISCHARGED. ADVANCED WATER TREATMENT METHODS MUST BE USED TO ELIMINATE THE POLLUTANTS GENERATED FROM CONTACT WITH THE PROCESS. THE FINAL STEP IS TO ELIMINATE THE BUILDUP OF TOTAL DISSOLVED SOLIDS OR THE CONCENTRATION OF INORGANIC SALTS WHICH RESULTS FROM REPEATED RECYCLING. THIS CAN BE ACCOMPLISHED BY ION EXCHANGE TECHNIQUES, DEMINERALIZATION, OR REVERSE OSMOSIS. IN THE LATTER CASE, THE REJECT BRINE STREAM IS THEN EVAPORATED TO DRYNESS. ONE PROJECTED ESTIMATE FOR A LARGE STEEL MILL COMPLEX SUGGESTS THAT ATTAINMENT OF ZERO DISCHARGE FROM ITS EXISTING FACILITIES WOULD GENERATE 152 TONS PER DAY OF SOLUBLE DRIED SOLIDS, WHICH THEN MUST BE DISPOSED OF IN A LANDFILL.

ECONOMICS AND REALITIES OF WATER TREATMENT FOR INDUSTRY

THE PROBLEM OF WATER POLLUTION DOES NOT EXIST IN A VACUUM. THERE ARE MANY CONSTRAINTS--ECONOMIC, TECHNICAL, SOCIAL, AND ENVIRONMENTAL--WHICH AFFECT AND DETERMINE THE COURSES OF ACTION TO BE TAKEN. THE OPTIMUM RESPONSE TO DIMINISHING MAN'S IMPACT ON HIS ENVIRONMENT, WHETHER IT BE WATER, AIR, OR LAND, IS NOT ALWAYS IMMEDIATELY CLEAR NOR EASILY DETERMINED. THIS SECTION WILL SEEK TO IDENTIFY SOME OF THE CONSTRAINTS -- I.E., THE PHYSICAL PROBLEM OF POLLUTANT REMOVAL: THE TREMENDOUS BURDEN OF POLLUTION CONTROL EQUIPMENT EXPENSE, OPERATION, AND MAINTENANCE: AND THE TROUBLING PROBLEM OF TRADE-OFFS. THE FINAL DISCUSSION DEALS BRIEFLY WITH THE QUESTION, "HOW CLEAN IS CLEAN?"

DIMINISHING RETURNS

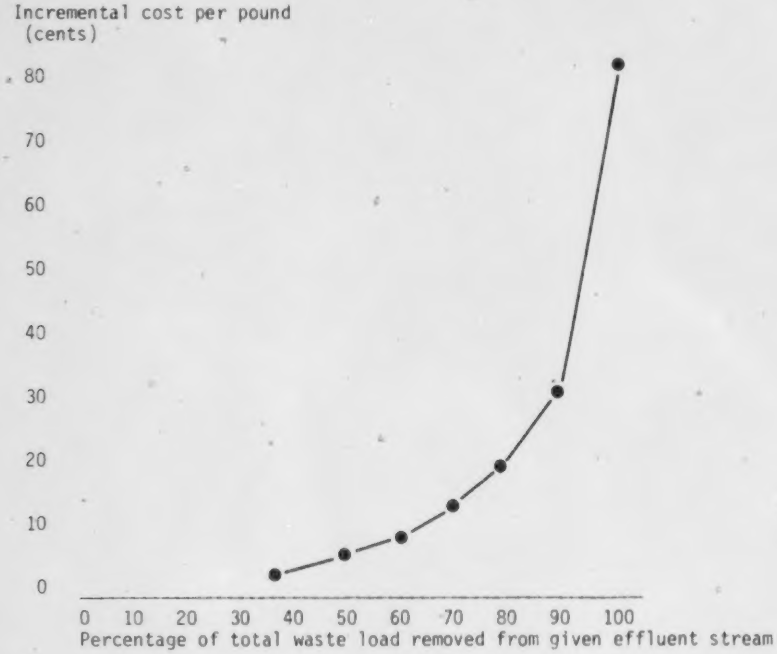
IN EVALUATING WASTE TREATMENT PROGRAMS AND SPECIFYING POLLUTION CONTROL OBJECTIVES, ONE THING WHICH MUST BE UNDERSTOOD IS THE PHYSICAL LIMITATION WHICH EXISTS REGARDING POLLUTANT REMOVAL. THE EXTRACTION OF GREATER AND GREATER AMOUNTS OF POLLUTANTS FROM EITHER A WATER OR AIR DISCHARGE STREAM BECOMES INCREASINGLY MORE DIFFICULT. THE BASIC LAWS OF PHYSICAL CHEMISTRY AND THERMODYNAMICS DICTATE THAT THE EFFICIENCY OF REMOVAL OF ONE PHASE (E.G., POLLUTANT) FROM ANOTHER (E.G., WATER) IS DIRECTLY PROPORTIONAL TO ITS CONCENTRATION. THE LOWER THE CONCENTRATION OF THE POLLUTANT, THE LOWER IS THE REMOVAL EFFICIENCY. THE POINT IS THAT, WHILE TOTAL POLLUTANT-REMOVAL MAY BE DESIRABLE, THERE ARE PRACTICAL LIMITS TO THE DEGREE OF "PURIFICATION" WHICH CAN TAKE PLACE. THE BASIC PROBLEM IS ONE OF EVER-INCREASING DILUTION AS A POLLUTANT IS REMOVED. EVENTUALLY, THE TASK BECOMES ONE OF LOOKING FOR THE PROVERBIAL "NEEDLE IN THE HAYSTACK". THE QUEST FOR GREATER AND GREATER WATER PURITY IS MANIFESTED IN SPIRALING EQUIPMENT AND OPERATING COSTS AND IN INCREASED ENERGY CONSUMPTION AND OTHER TRADE-OFFS.

CAPITAL COSTS AND OPERATING EXPENSES

POLLUTION CONTROL HAS BECOME A MAJOR INDUSTRY IN THE UNITED STATES AS MORE STRINGENT REGULATIONS ON BOTH WATER AND AIR DISCHARGES BECOME EFFECTIVE. THE COSTS OF MEETING BEST PRACTICAL TECHNOLOGY STANDARDS (BPT) HAVE BEEN CONSIDERABLE, AND THE COSTS OF ATTAINING BEST AVAILABLE TECHNOLOGY STANDARDS (BAT) ARE LIKELY TO BE SEVERAL TIMES BPT COSTS. THE COST OF ATTAINING THE ZERO DISCHARGE LEVEL WILL BE ENORMOUS.

THE PROBLEM CAN BE DEMONSTRATED AS FOLLOWS. THE ATTAINMENT OF A HIGH DEGREE OF PURIFICATION CAN BE OBTAINED AT A REASONABLE EXPENSE OF CAPITAL AND POWER, BUT SUPER-PURITY REQUIRES TREMENDOUS EXPENSE. WHILE BPT CLEANING OF 95-97% POLLUTANT REMOVAL IS COSTLY, BUT NEVERTHELESS PRACTICAL, BAT CLEANING OF 98-99% POLLUTANT REMOVAL MAY DOUBLE OR TRIPLE THE COSTS OF INSTALLATION AND OPERATION. ZERO DISCHARGE OR ESSENTIALLY 100% POLLUTANT REMOVAL MAY BE PROHIBITIVE IN TERMS OF COST IF NOT IMPOSSIBLE TECHNICALLY TO ATTAIN. THE PROBLEM IS INDICATED IN FIGURE 8, WHICH GIVES THE MARGINAL COSTS OF POLLUTION CONTROL.

Figure 8. Example of Marginal Costs of Pollution Control (Freeman, 1978).



Clearly, the marginal cost, or the cost of removing the next increment of pollutant from the effluent stream, rises modestly at first, but then ever more steeply as high levels of pollutant removal are achieved. This effect is also shown in Table V below, based on data points from Figure 10.

Table V.

% of Waste Removal	Incremental Cost Per Pound Of Pollutant Removed	Cost Increase Per 9% Increment
81%	$.18/Lb.	
90%	$.30/Lb.	$.12/Lb.
99%	$.80/Lb.	$.50/Lb.

A. Myrick Freeman III (1978) in Current Issues in U.S. Environmental Policy suggests that:

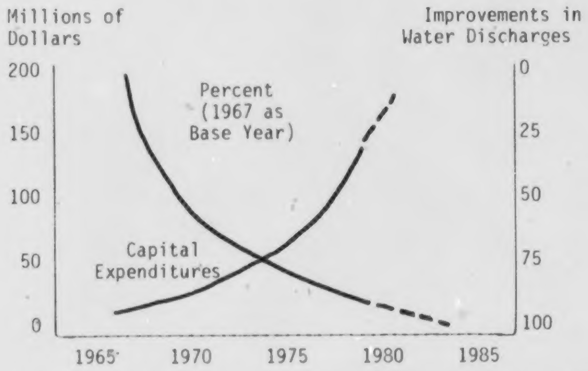
> "A more sensible approach would be to make the prevention of adverse effects of water pollution the primary objective of water pollution policy, with the proviso that the nature and magnitude of these adverse effects be compared with the costs of their prevention. That is, benefits and costs would be balanced at the margin."

A specific example of this problem of diminishing returns for an existing steel company is

INDICATED IN FIGURE 9. THE FIGURE SHOWS THAT FOR INLAND STEEL COMPANY THE REMOVAL OF SUSPENDED SOLIDS AND OILS BY 1977 HAD REACHED 80% OF THOSE LEVELS PRESENT IN 1967, BUT AT A CAPITAL COST OF $80 MILLION. FURTHER SMALL INCREASES IN POLLUTANT REMOVAL WOULD ONLY BE ACHIEVED WITH SIGNIFICANTLY GREATER CAPITAL EXPENDITURES. PARALLELING FIGURE 9, THE YEARLY INCREASE IN OPERATING COSTS OF AIR AND WATER CONTROL FACILITIES AT INLAND STEEL COMPANY ARE SHOWN IN FIGURE 10. OPERATING COST TRENDS ARE, OF COURSE, UP SHARPLY AS INCREASINGLY MORE SOPHISTICATED POLLUTION CONTROL EQUIPMENT IS INSTALLED.

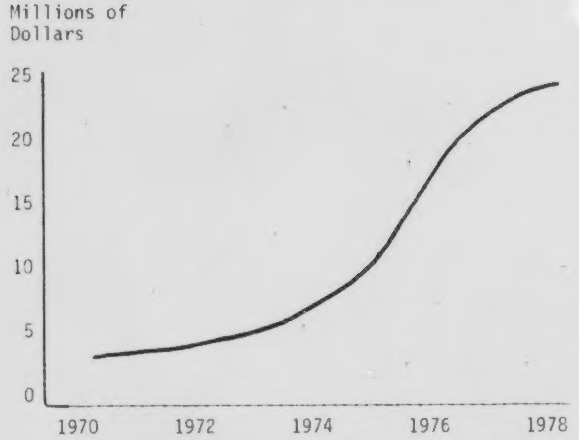
THE PROBLEMS OF TRADE-OFFS

THE EVER MORE-STRINGENT REQUIREMENTS TO CONTROL WASTEWATER DISCHARGES AS MANIFESTED IN BPT, BAT, AND FINALLY ZERO DISCHARGE EFFLUENT GUIDELINES ARE NOT WITHOUT THEIR OFFSETTING ADVERSE EFFECTS IN OTHER AREAS. TO POINT UP THIS PROBLEM AND INDICATE THE COMPLEXITY OF SORTING OUT THE VARIOUS OFFSETTING ENVIRONMENTAL IMPACTS, A SPECIFIC STUDY WILL BE CONSIDERED.



In the field of water pollution control, Inland has spent $80 million in capital projects to achieve a reduction of 80% since 1967 in the level of discharged solids and oils.

FIGURE 9. PROGRESS IN WATER QUALITY (INLAND STEEL, 1978).



In addition to the $200 million spent for air and water pollution control facilities, Inland spends about $25 million annually to operate these systems.

Figure 10. Operating Cost Trend Air & Water Control Facilities (Inland Steel, 1978).

Dr. K. J. Yost and D. E. Gergely of Purdue University authored in 1977 an analysis for the American Iron and Steel Institute entitled, "The Net Environmental Impact of Proposed EPA Effluent Guidelines for the Blast Furnace and Basic Oxygen Furnace". Their study was an attempt to quantify the net environmental impact of moving from BPT (Best Practicable Control Technology Currently Available) effluent guidelines by July 1, 1977, to BAT (Best Available Technology Economically Achievable) effluent guidelines by July 1, 1983, for various pollutants as proposed by the EPA for aqueous discharges from blast furnace (BF) and basic oxygen furnace (BOF) processes.

The positive environmental impact of reduced wastewater pollutant discharges of 8,176,000 Kg/yr (9,000 tons/year) for the entire U. S. steel industry is indicated in Table VI. This positive impact was then evaluated against the following negative impacts:

1. Supporting industry air, water, and sludge discharges associated with production of treatment chemicals and treatment plant electrical energy requirements.
2. The formation of possible toxic substances (chlorinated hydrocarbons) as a result of the BAT chlorination treatment of blast furnace and basic oxygen furnace wastewater streams.
3. The increased energy consumption and increased raw material usage needed to produce the additional treatment chemicals and operate the BAT treatment facilities.

TABLE VI. REDUCTION IN ANNUAL POLLUTANT DISCHARGE RATES ASSOCIATED WITH COMPLIANCE WITH BATEA, AS OPPOSED TO BPCTCA, EFFLUENT GUIDELINES*(YOST AND GERGELY, 1977).

Blast Furnace		Basic Oxygen Furnace	
POLLUTANT PARAMETER	BPCTCA MINUS BATEA TIMES ANNUAL PRODUCTION IN U.S.	POLLUTANT PARAMETER	BPCTCA MINUS BATEA TIMES ANNUAL PRODUCTION IN U.S.
Suspended Solids	1,622,400 kg/yr	Total Suspended Solids	312,000 kg/yr
Cyanide	---------	Fluoride	378,000 kg/yr
Phenol	143,520 kg/yr	pH	-----------
Ammonia	4,672,200 kg/yr		
pH	---------		
Sulfide	237,120 kg/yr		
Fluoride	811,200 kg/yr		
Subtotal	7,486,440 kg/yr		690,000 kg/yr
		TOTAL	8,176,440 kg/yr (9,000 ton/yr)

*Based on annual production rates of 78,000,000 metric tons for the Blast Furnace, and 60,000,000 metric tons for the Basic Oxygen Furnace.

YOST'S CATEGORIZATION OF TRADE-OFFS IS STARTLING IF NOT DISQUIETING. HIS CONCLUSIONS ARE ESSENTIALLY AS FOLLOWS.

1. AS INDICATED ABOVE, THE POSITIVE ENVIRONMENTAL IMPACT RESULTS FROM A REDUCTION IN STEEL MILL POLLUTANT DISCHARGES TO THE NATION'S WATERWAYS OF ABOUT 9,000 TONS/YEAR OF SUSPENDED SOLIDS, CYANIDE, PHENOL, AMMONIA, SULFIDE, AND FLUORIDE. THIS ACHIEVEMENT, HOWEVER, IS SOMEWHAT TEMPERED BY THE FACT THAT CYANIDE WOULD NOT BE SIGNIFICANTLY REDUCED BELOW BPT LEVELS BECAUSE NEARLY ALL CYANIDE IN THE EXISTING PROCESS RECYCLE STREAMS IS TIED UP IN COMPLEX COMPOUNDS AND DOES NOT RESPOND TO OXIDATION BY CHLORINATION TREATMENT. HE FURTHER POINTS OUT THAT A MODELING STUDY OF POINT SOURCE DISCHARGES INDICATES ONLY A MINOR REDUCTION IN THE RADII OF SPHERICAL LAKE ZONE CONCENTRATIONS IN MOVING FROM BPT TO BAT. HE ALSO POINTS OUT THAT SEVERAL OF THE POLLUTANTS SUCH AS AMMONIA, PHENOL, AND CYANIDE ARE BIODEGRADEABLE IN LAKES AND STREAMS. HE, THEREFORE, CONCLUDES THAT THE POSITIVE ENVIRONMENTAL IMPACT OF ACHIEVING BAT IS "RELATIVELY INSIGNIFICANT".
2. THE NEGATIVE IMPACT OF BAT IMPLEMENTATION OCCURS IN THE ENVIRONMENTAL, HEALTH, AND RESOURCE AREAS AS FOLLOWS:
   A. THE DISCHARGES BY PRIMARY SUPPORTING INDUSTRIES ASSOCIATED WITH THE PRODUCTION OF TREATMENT CHEMICALS SUCH AS LIME, CHLORINE, SULFURIC ACID, AND ACTIVATED CARBON, AND THE DISCHARGES FROM POWER PLANTS TO SUPPLY ELECTRICAL

ENERGY TO RUN THE BAT TREATMENT PLANTS ARE AS FOLLOWS:

(1) AIR DISCHARGES -- 12,200 TONS/YEAR OF VARIOUS AIR POLLUTANTS -- A SIGNIFICANT RESPIRATORY HEALTH HAZARD.

(2) WATER DISCHARGES -- 50 TONS/YEAR.

(3) SLUDGE -- 12,400 TONS/YEAR, A DISPOSAL PROBLEM WHICH WILL REQUIRE UNDER NEW SOLID WASTE REGULATIONS PROCESSING FACILITIES, ENERGY CONSUMPTION, AND TREATMENT CHEMICALS.

B. DISCHARGES BY SECONDARY SUPPORTING INDUSTRIES WERE NOT QUANTIFIED, BUT WOULD CONSTITUTE AN ADDITIONAL ENVIRONMENTAL BURDEN RESULTING FROM RAW MATERIAL, MINING, AND TRANSPORTATION OPERATIONS.

C. THE FORMATION OF SOME TOXIC LONG-LASTING OR PERSISTENT CHLORINATED HYDROCARBONS OCCURS AS A RESULT OF BAT CHLORINATION OF ORGANICS PRESENT IN BLAST FURNACE WASTEWATER. THESE CHEMICALS, ALTHOUGH IN SMALL AMOUNTS, WOULD BE DISCHARGED TO THE NATION'S WATERWAYS, AND WOULD POSE A LONG-TERM HEALTH HAZARD.

D. ENERGY REQUIREMENTS TO RUN THE BAT TREATMENT FACILITIES AND PRODUCE TREATMENT CHEMICALS WOULD AMOUNT TO AN ADDITIONAL 245,000 MEGA WATT HOURS OF ELECTRICITY PER YEAR. THIS TRANSLATES TO ABOUT 370,000 BARRELS OF OIL OR 111,000 TONS OF COAL PER YEAR CONSUMED. THE ENERGY REQUIREMENTS FOR SECONDARY SUPPORTING INDUSTRIES HAVE NOT BEEN INCLUDED.

E. ABOUT 191,000 TONS/YEAR OF VALUABLE TREATMENT CHEMICALS WOULD BE CONSUMED IN BAT TREATMENT FACILITIES.

DR. YOST SUMMARIZES HIS CONCLUSIONS AS FOLLOWS:

> "Clearly, the net effect of the implementation of BATEA effluent guidelines for the nation's blast furnace and basic oxygen furnace processes is, at best, questionable. To secure a relatively minor reduction in aqueous discharges from steel plants where a minimal health problem is apparently involved will, on the other hand, mean increased air pollution: the possible formation of toxic substances and their injection into waterways: and finally, an added burden on the nation's energy and raw material supply system."

THE ABOVE EXAMPLE MAY OR MAY NOT PROVE THE ADVISABILITY OF MEETING BAT STANDARDS IN THIS ONE SPECIFIC CASE, BUT IT DOES POINT OUT THE MANY FACTORS WHICH SHOULD BE CONSIDERED WHEN MORE STRINGENT EFFLUENT STANDARDS ARE PROPOSED. WHATEVER COURSE OF ACTION IS CHOSEN, WE SHOULD BE SURE THAT A NET ENVIRONMENTAL IMPROVEMENT EXISTS WHICH WILL SUBSTANTIALLY OFFSET ALL OTHER NEGATIVE IMPACTS: OTHERWISE THERE WILL JUST BE A WASTE OF TIME, RESOURCES, AND MONEY TO SHOW FOR GOOD INTENTIONS.

How Clean is Clean?

In the context of the foregoing discussion, the question regarding desirable water quality -- "How clean is clean?" -- then becomes of utmost importance. Pure water, that is water devoid of impurities, is essentially a laboratory curiosity. It is the impurities in water which give it its character, good or bad. Man could not survive drinking distilled (pure) water because it leaches away body salts necessary to life. Water, then, with a mix of impurities is the natural state of affairs. Absolutely pure water is actually neither achievable or desirable as a discharge objective. The balance which must be attained in the national water pollution control effort is that level of water quality which, in the words of the Clean Water Act, "restore(s) and maintain(s) the chemical, physical, and biological integrity of the Nation's waters." Assessment of that desired water integrity must, however, account for and adjust to the other social, technical, and economic factors which are sometimes complementary and oftentimes competitive. Unfortunately, in our complex society, "clean water" cannot be absolutely defined, but is of necessity some kind of compromise.

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APPENDIX

Appendix EPA-1 is an excerpt from a recent permit actually issued under the Federal Water Pollution Control Act.

AUTHORIZATION TO DISCHARGE UNDER THE
NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM

In compliance with the provisions of the Federal Water Pollution Control Act, as amended, (33 U.S.C. 1251 et. seq; the "Act"),

is authorized to discharge from a facility located at.... (location deleted)

to receiving waters named...Ohio River

in accordance with effluent limitations, monitoring requirements and other conditions set forth in Parts I, II, and III hereof.

This permit shall become effective on...January 24, 1975

This permit and the authorization to discharge shall expire at midnight,...January 24, 1980

Signed this..24th.. day of...December, 1974

Stephen R. Wassersug
Director, Enforcement Division
U.S. Environmental Protection Agency
Region III

A. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

During the period beginning...effective date...and lasting through...June 30, 1977 the permittee is authorized to discharge from outfall(s) serial number(s)...102

Such discharges shall be limited and monitored by the permittee as specified below:

Effluent Characteristic	Discharge Limitations				Monitoring Requirements	
	kg/day (lbs/day) Net		Other Units (specify)		Measurement Frequency	Sample Type
	Daily Avg	Daily Max	Daily Avg	Daily Max		
Flow-m^3/Day (MGD)	N/A	N/A	N/A	N/A	1/week	measured
Total Suspended Solids	N/A	N/A	N/A	N/A	1/week	grab
Cyanide	186(261)	355(783)	N/A	N/A	1/week	grab
Cyanide "A"	14.5(32)	43.6(96)	0.2mg/l	0.6mg/l	1/week	grab

The pH shall not be less than...N/A...standard units nor greater than...N/A...standard units and shall be monitored 1/week by grab sample

There shall be no discharge of floating solids or visible foam in other than trace amounts.

Samples taken in compliance with the monitoring requirements specified above shall be taken at the following location(s):...

Sampling point 102 - The discharge from the sinter plant and blast furnace waste treatment facility, prior to dilution.

A. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

During the period beginning...July 1, 1977...and lasting through...expiration date the permittee is authorized to discharge from outfall(s) serial number(s)...102...

Such discharges shall be limited and monitored by the permittee as specified below:

EFFLUENT CHARACTERISTIC	DISCHARGE LIMITATIONS				MONITORING REQUIREMENTS	
	kg/day (lbs/day) Net		Other Units (specify)		Measurement Frequency	Sample Type
	Daily Avg	Daily Max	Daily Avg	Daily Max		
Flow-m^3/Day (MGD)	N/A	N/A	N/A	N/A	continuous	recorded
Total Suspended Solids	260(574)	781(1722)	N/A	N/A	3/week	24hr.compos.
Cyanide	60.0(130)	177(390)	N/A	N/A	3/week	24hr.compos.
Ammonia	411(906)	1334(2718)	N/A	N/A	3/week	24hr.compos.
Phenol	15.6(34.4)	46.8(103.2)	N/A	N/A	3/week	24hr.compos.
Oil & Grease	N/A	N/A	10 mg/l	15 mg/l	3/week	3 grabs/24hr.
Cyanide "A"	1.77(3.9)	5.3(11.7)	N/A	N/A	3/week	24hr.compos.

The pH shall not be less than...6.0...standard units nor greater than...9.0...standard units and shall be monitored...continuous - recorded...

There shall be no discharge of floating solids or visible foam in other than trace amounts.

Samples taken in compliance with the monitoring requirements specified above shall be taken at the following location(s):

...Sampling point 102 - at the discharge from the sinter plant and blast furnace waste treatment facility, prior to dilution. ...

9. Property Rights

The issuance of this permit does not convey any property rights in either real or personal property, or any exclusive privileges, nor does it authorize any injury to private property or any invasion of personal rights, nor any infringement of Federal, State or local laws or regulations.

10. Servability

The provisions of this permit are severable, and if any provision of this permit, or the application of any provision of this permit to any circumstance, is held invalid, the application of such provision to other circumstances, and the remainder of this permit, shall not be affected thereby.

PART III

OTHER REQUIREMENTS....

1. Monitoring: The intake waters shall be monitored & reported concurrently & or the same basis as the effluent where the limitations are based on the permittee's addition of pollutants to the waste water (i.e., net effluent loadings). The South Mill pump house shall be monitored for outfalls 013, 015, 017, 018, 019, 020 & 025. The Logstown run pump house shall be monitored for all other outfalls.

2. The discharge shall not cause a rise in the stream temperature of more than 5 F above the ambient or a maximum of 87 F whichever is less; not to be changed by more than 2 F during any one hour period.

3. The permittee agrees to reimburse the U.S. Army Corps of Engineers for those expenses incurred in removal of materials from the navigable waterway resulting from his activities and affecting navigation and/or anchorage.. Reimbursement shall be made to the District Engineer within ten (10) days following receipt of a written assessment of these expenses. In determining this data and information submitted by the permittee in his application for this permit, the terms and conditions of this permit, the data and information accumulated during the periodic monitoring of this authorized discharge, the location of the discharge, the proximity, nature and type of other discharges in the vicinity of the permittee's discharge, the past and existing navigable capacity and the dimensions of the waterway into which the discharge is made, the extent and cost of dredging required to restore the navigable capacity of the waterway to its normal condition, and any other pertinent data which the permittee or any other party may furnish.

4. The permittee shall apply to the Pennsylvania Department of Environmental Resources within ninety (90) days of the effective date of this permit for a Water Quality Management permit pursuant to state law for the discharges described in this permit.

TABLE IV WATER EFFLUENT STANDARDS

	TYPE OF SOURCE	POLLUTANTS	DATE EFFECTIVE	BY WHOM ESTABLISHED	ENFORCEMENT MECHANISM	S C O P E
Water Quality Standards	Not a "Source" --Rivers, Streams, Lakes, & All Surface Waters	Various	July 1, 1984	States/EPA Approval	Permits/State Programs for Nonpoint Sources	All surface waters except those specifically approved by EPA for less stringent classification.
Best Practicable Control Technology (BPT)	Industry & Major Feedlots (Existing)	Various	July 1, 1977	EPA	Permits (NPDES)	Add-On Treatment Technology--Includes Process Changes
Best Conventional Pollutant Control Technology (BCT)	Industry, Feedlots, & Municipalities	pH, BOD, TSS, Fecal Coliform	July 1, 1984	EPA	Permits (NPDES)	Downgraded these pollutants from BAT requirements to something above BPT.
Nonconventional or "Gray Area" (BAT)	Industry	Pollutants not in toxic or conventional categories.	July 1, 1984, or as appropriate.	EPA	Permits (NPDES)	Can be allowed variances from BAT on economic or environmental grounds.
Best Available Technology Economically Achievable (BAT)	Industry	Toxic	July 1, 1984, or as appropriate for 129 toxics.	EPA	Permits (NPDES)	Unlimited--Any changes needed to prohibit/limit toxics.
Best Management Practices (BMP's)			None	EPA	Permits (NPDES)	Practices to Limit Runoff, Spills, Etc.
Effluent Standards			Up to 1 year after promulgation or as appropriate for added toxics.	EPA	Permits (NPDES)	Unlimited--Any changes needed to prohibit/limit toxics.
Pretreatment Effluent Standards	Industries Introducing Wastes into Publicly-Owned Treatment Plants	Toxic	Within 3 years of promulgation of standards.	EPA	Permit	Must remove any pollutant the POTW cannot treat.

SPECIAL ISSUES

JOSEPH J. DELFINO

JOSEPH J. DELFINO is an associate professor of water chemistry in the Department of Civil and Environmental Engineering at the University of Wisconsin-Madison. He is also Chief of the environmental sciences section of the State Laboratory of Hygiene. A chemist by trade, Joe has written numerous articles on heavy metal transformations within aquatic ecosystems. He has been active in spearheading work at the State Laboratory of Hygiene on hazardous and toxicological substances in public water supplies. Among other responsibilities, he has been a member of the Joint Task group that has prepared the standard methods used to examine water and wastewater; a member of the executive committee of the environmental chemistry division of the American Chemical Society; and a consultant for the U.S. Fish and Wildlife Service.

Aside from his professional activities he enjoys dancing, squash, and walking. He is married and has one daughter.

FOREWORD

THIS REPORT WAS PREPARED FOR A COURSE ON WATER QUALITY ISSUES ENTITLED "DECISIONS FOR LAKE MICHIGAN" OFFERED BY THE INTERSTATE WATER QUALITY TRAINING PROGRAM AND COORDINATED BY THE PURDUE UNIVERSITY CALUMET CAMPUS.

THE INTENDED AUDIENCE FOR THIS REPORT INCLUDES INFORMED CITY AND COUNTY OFFICIALS, STATE LEGISLATORS, ENVIRONMENTALISTS, REPRESENTATIVES OF INDUSTRY AND CITIZENS CONCERNED WITH WATER QUALITY IN THE GREAT LAKES. THE REPORT ATTEMPTS TO PROVIDE A BASIC UNDERSTANDING OF THE TOXIC SUBSTANCES PROBLEM IN THE GREAT LAKES WITH EMPHASIS ON LAKE MICHIGAN.

THE REPORT IS NOT INTENDED TO BE AN EXHAUSTIVE SCIENTIFIC TREATISE ON THE SUBJECT MATTER. IT WILL BE MANY YEARS BEFORE ENOUGH INFORMATION IS AVAILABLE FOR SUCH A TASK TO BE SUCCESSFUL. ALSO, THE REPORT IS NOT COMPLETELY BALANCED IN ITS SUBJECT TREATMENT IN THAT CERTAIN TOPICS ARE GIVEN FAR MORE COVERAGE THAN OTHERS. THIS IS A REFLECTION OF THE INTERESTS AND EXPERIENCES OF THE AUTHOR RATHER THAN THE RELATIVE AMOUNT OF INFORMATION AVAILABLE ON THE VARIOUS ASPECTS OF TOXIC SUBSTANCES IN THE LAKES.

ANYONE WISHING TO OBTAIN INFORMATION BEYOND THAT PROVIDED IN THIS REPORT AND ITS REFERENCES SHOULD CONTACT ANY OF THE FOLLOWING: THE GREAT LAKES BASIN COMMISSION, ANN ARBOR, MI; REGION V, US EPA, CHICAGO, IL: OR THE STATE DEPARTMENTS OF NATURAL RESOURCES AND APPROPRIATE LIBRARIES AT THE MAJOR UNIVERSITIES IN EACH OF THE STATES SURROUNDING THE GREAT LAKES. OF PARTICULAR VALUE IN THE LATTER CATEGORY ARE THE WATER RESOURCES CENTERS AND THE SEA GRANT PROGRAMS THAT ARE LOCATED IN MOST OF THE GREAT LAKE STATES, USUALLY ON THE LAND GRANT COLLEGE CAMPUSES.

TOXIC SUBSTANCES IN THE GREAT LAKES

By

Joseph J. Delfino

HISTORICAL INTRODUCTION

Concern over the presence of chemicals in the Great Lakes is a relatively recent phenomenon. Beeton (1969) reviewed historical trends in the concentrations of chemicals in the lakes and found those, such as calcium, magnesium, sodium, potassium, chloride, nitrate and phosphorus, to have increased in the past 50 years or so. The changes in chemical concentrations were accompanied by changes in the biota, particularly changes in the composition of the algae populations from so-called clean water forms to those indicating early signs of eutrophication. Beeton's thesis was that man's activities were influencing the limnology of the Great Lakes; the result was an increase in eutrophic (well nourished; excessively fertilized) conditions. These were noted in some of the lakes, particularly Lakes Erie and Ontario but also sections of Lake Michigan, especially the southern basin and Green Bay.

An international conference held in Madison, Wisconsin in 1967 focused on the subject of eutrophication and spurred greater research interest in this topic. Soon thereafter, in the early 1970's, the eutrophication issue was confounded by an intense discussion over the potential effects of thermal pollution in the Great Lakes. With the advent of increased demands for electric power, especially in the mid-west, a number of power plants (including several that were nuclear fueled) were constructed on the shores of the Great Lakes. Concerned citizens and regulatory agencies, already alarmed by the spectre of decreased water quality brought about by increased eutrophication, challenged the practice of allowing utilities to discharge heated water directly from power plant cooling systems into the lakes. By 1972, these two issues created sufficient regulatory attention that an interstate enforcement conference was convened to address increased phosphorus and thermal additions to the lakes, particularly Lake Michigan.

While the environmental debates in the early 1970's emphasized the phosphorus and thermal pollution issues, another major problem was being recognized for the first time. The first serious alert concerned pesticides and was sounded by Rachel Carson in The Silent Spring published in 1962. But, it was not until the late 1960's that the combination of increased environmental awareness and laboratory analytical capability led to the finding of pesticides throughout the world. The Great Lakes and its fishes were no exception (LMIPC, 1972). The chemical stability of some of the pesticides, coupled with the biochemistry of fish, resulted in significant concentrations of compounds such as DDT and

DIELDRIN ACCUMULATING IN FISH. THOSE FISH THAT WERE TO BE SOLD COMMERCIALLY COULD NOT BE MARKETED IF THEY CONTAINED MORE THAN 5 PPM (PARTS PER MILLION; MICROGRAMS PER GRAM) OF DDT, BECAUSE THE US FDA HAD SET THIS VALUE AS THE ACCEPTABLE OR TOLERANCE LEVEL.

DURING THE EXTENSIVE EFFORT THAT WAS MOUNTED TO DOCUMENT DDT LEVELS IN VARIOUS GREAT LAKES FISH SPECIES, CHEMISTS BEGAN TO NOTE THE PRESENCE OF ADDITIONAL COMPOUNDS THAT WERE CO-ANALYZED WITH DDT AND DIELDRIN AND, IN FACT, SOME OF THESE SUBSTANCES CREATED SIGNIFICANT PROBLEMS IN THE QUANTITATIVE ANALYSIS FOR THESE SUBSTANCES IN FISH. IT WAS SOON RECOGNIZED THAT THESE TROUBLESOME COMPOUNDS WERE POLYCHLORINATED BIPHENYLS (PCBS) AND THAT THEY WERE ALSO PRESENT IN SIGNIFICANT AMOUNTS (1 TO 25 PPM) IN LAKE MICHIGAN FISH (VEITH, 1973).

THUS, WHAT DEVELOPED ORIGINALLY AS A PROBLEM OF THE APPLICATION OF NONDEGRADABLE PESTICIDES SUCH AS DDT - AND THEIR SUBSEQUENT TRANSPORT TO THE GREAT LAKES - SOON BLOSSOMED INTO THE MAJOR ISSUE OF CONTAMINATION BY TOXIC SUBSTANCES.

THERE IS STILL CONCERN, TO BE SURE, OVER THE CONTINUAL INFLUX OF PHOSPHORUS INTO THE GREAT LAKES (PLUARG, 1978) AND, TO A LESSER EXTENT, THE ISSUE OF THERMAL DISCHARGES. BUT, IT IS CLEAR THAT TOXIC SUBSTANCES HAVE NOW BECOME THE PREDOMINANT WATER QUALITY ISSUE IN THE GREAT LAKES BASIN (PLUARG, 1978).

DEFINITION OF A TOXIC SUBSTANCE

THE TERM TOXIC, AS DEFINED IN WEBSTER'S SEVENTH NEW COLLEGIATE DICTIONARY, IS SOMETHING "OF, RELATING TO OR CAUSED BY A POISON OR TOXIN", WHERE A POISON IS "A SUBSTANCE THAT THROUGH ITS CHEMICAL ACTION USUALLY KILLS, INJURES OR IMPAIRS AN ORGANISM". CLEARLY, TOXIC SUBSTANCES, BY THEIR VERY NATURE, ARE CERTAINLY A HIGH PRIORITY ISSUE THAT MERITS SERIOUS ATTENTION IN THE GREAT LAKES.

THE CONGRESS OF THE UNITED STATES ADDED A LEGAL DEFINITION OF TOXIC SUBSTANCES WHEN, IN OCTOBER OF 1976, IT ENACTED THE TOXIC SUBSTANCES CONTROL ACT (PUBLIC LAW 94-469). TOXIC SUBSTANCES WERE DEFINED THEREIN AS THOSE CHEMICAL SUBSTANCES "WHOSE MANUFACTURE, PROCESSING, DISTRIBUTION IN COMMERCE, USE OR DISPOSAL MAY PRESENT AN UNREASONABLE RISK OF INJURY TO HEALTH OR THE ENVIRONMENT."

IT IS CLEAR THAT NUMEROUS INDUSTRIAL CHEMICALS, SUCH AS PCBS, HAVE BEEN ENTERING THE ENVIRONMENT FOR MANY YEARS AND, LIKE DDT, HAVE ACCUMULATED IN LIVING ORGAMISMS INCLUDING GREAT LAKES FISH AND HUMANS (US EPA, 1976). POLYCHLORINATED BIPHENYLS HAVE BEEN IDENTIFIED ESSENTIALLY EVERYWHERE IN THE WORLD (RISEBROUGH, 1976), DESPITE THE FACT THAT THESE SUBSTANCES WERE PRODUCED FOR USES THAT INITIALLY SHOULD NOT HAVE RESULTED IN SUCH WIDESPREAD DISTRIBUTION. IT IS SOMEWHAT EASY TO SEE HOW DDT, FOR EXAMPLE, ENTERED THE GREAT LAKES SINCE IT WAS WIDELY USED AS AN AGRICULTURAL PESTICIDE IN THE BASIN AND WAS TRANSPORTED TO THE LAKES BY THE ATMOSPHERE OR CARRIED BY RUNOFF TO TRIBUTARIES EMPTYING INTO THE LAKES.

The PCBs and related industrial chemicals were not manufactured for purposes related to agriculture. Rather, they were produced for inclusion in sealed capacitors, transformers, hydraulic fluids, etc. (Durfee, 1976). None of these commercial applications proved to be sufficiently "closed" to prevent PCBs from escaping into the world's ecosystems. This experience hopefully will not be repeated again in the United States as the Toxic Substances Control Act is implemented.

One unanswered question involves the use of PCBs elsewhere in the world. Many countries still allow the use of PCBs and related toxic industrial compounds and these can be distributed throughout the world through various global-scale circulation processes, involving both the atmosphere and the oceans.

Examples of Toxic Substances

A substance is considered toxic if it fulfills the requirements of the definitions (dictionary and/or legal) given above. However, it is known that any substance, taken in excess, will be toxic to some organism in a given circumstance. Therefore, certain boundary conditions have to be established in discussing toxic substances. Chemicals can generally be classified as inorganic or organic substances. There are thousands of inorganic compounds and literally millions of organic compounds known to scientists. One way to classify toxic substances is to simply check standard reference texts that give data on the toxicity of substances to various organisms. However, some of the data are likely to be contradictory and, more importantly, there likely will be serious omissions from the references whenever a specific chemical is under scrutiny. Thus, there is a lot of confusion as to just what the proper way of seeking information about toxic chemicals happens to be.

A legal decision in 1976 provided one useful start to the toxic substance situation. Prior to the passage and implementation of the Toxic Substances Control Act, it was assumed that the US EPA would control the discharge of (toxic) pollutants through mechanisms established under the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500). Apparently the EPA was not moving quickly enough since the Natural Resources Defense Council and the Environmental Defense Fund sued the EPA in Federal court for failure to regulate toxic pollutants by promulgating effluent guidelines.

The court ruling, known as the "Flannery Decision", is a significant milestone in the battle to control toxic substances in the environment. As part of the Decision, a list of "Priority Pollutants" or "Consent Decree Pollutants" was established. This list contains both inorganic and organic substances and represents the first group of toxic substances that must be regulated by EPA (Table 1). It can be expected that many more compounds will be added to the list as more toxicological data are developed.

TABLE 1. LIST OF EPA PRIORITY POLLUTANTS BASED ON THE FLANNERY DECISION.

1. *acenaphthene
2. *acrolein
3. *acrylonitrile
4. *benzene
5. *benzidine
6. *carbon tetrachloride (tetrachloromethane)

*chlorinated benzenes (other than dichlorobenzenes)

7. chlorobenzene
8. 1,2,4-trichlorobenzene
9. hexachlorobenzene

*chlorinated ethanes (including 1,2-dichloroethane, 1,1,1,-trichloroethane and hexachloroethane)

10. 1,2-dichloroethane
11. 1,1,1,-trichloroethane
12. hexachloroethane
13. 1,1-dichloroethane
14. 1,1,2-trichloroethane
15. 1,1,2,2-tetrachloroethane
16. chloroethane

*chloroalkyl ethers (chloromethyl, chloroethyl and mixed ethers)

17. bis(chloromethyl) ether
18. bis(2-chloroethyl) ether
19. 2-chloroethyl vinyl ether (mixed)

*chlorinated naphthalene

20. 2-chloronaphthalene

*chlorinated phenols (other than those listed elsewhere; includes trichlorophenols and chlorinated cresols)

21. 2,4,6-trichlorophenol
22. parachlorometa cresol
23. *chloroform (trichloromethane)
24. *2-chlorophenol

*dichlorobenzenes

25. 1,2-dichlorobenzene
26. 1,3-dichlorobenzene
27. 1,4-dichlorobenzene

*dichlorobenzidine

28. 3,3-dichlorobenzidine

*dichlorethylenes(1,1-dichlorethylene and 1,2-dichloreothylene)

29. 1,1-dichloroethylene
30. 1,2-trans-dichloroethylene
31. *2,4-dichlorophenol

*dichloropropane and dichloropropene

32. 1,2-dichloropropane
33. 1,2-dichloropropylene (1,3-dichloropropene)
34. *2,4-dimethylphenol

*dinitrotoluene

35. 2,4-dinotrotoluene
36. 2,6-dinotrotoluene
37. *1,2-diphenylhydrazine
38. *ethylbenzene
39. *fluoranthene

*haloethers (other than those listed elsewhere)

40. 4-chlorophenyl phenyl ether
41. 4-bromophenyl phenyl ether
42. bis(2-chloroisopropyl) ether
43. bis(2-chloroethoxy) methane

*halomethanes (other than those listed elsewhere)

44. methylene chloride (dichloromethane)
45. methyl chloride (chloromethane)
46. methyl bromide (bromomethane)
47. bromoform (tribomomethane)
48. dichlorobromomethane
49. trichlorofluoromethane
50. dichlorodifluoromethane
51. chlorodibromomethane
52. *hexachlorobutadiene
53. *hexachlorocyclopentadiene
54. *isophorone
55. *naphthalene
56. *nitrobenzene

*nitrophenols (including 2,4-dinitrophenol and dinitrocresol)

57. 2-nitrophenol
58. 4-nitrophenol
59. *2,4-dinitrophenol
60. 4,6-dinitro-o-cresol

*nitrosamines

61. N-nitrosodimethylamine
62. N-nitrosodiphenylamine

63. N-nitrosodi-n-propylamine
64. *pentachlorophenol
65. *phenol
*phthalate esters
66. bis(2-ethylhexyl) phthalate
67. butyl benzyl phthalate
68. di-n-butyl phthalate
69. di-n-octyl phthalate
70. diethyl phthalate
71. dimethyl phthalate
*polynuclear aromatic hydrocarbons
72. benzo(a)anthracene (1,2-benzanthracene)
73. benzo(a)pyrene(3,4-benzopyrene)
74. 3,4-benzofluoranthene
75. benzo(k)fluoranthane (11,12-benzofluoranthene)
76. chrysene
77. acanphthylene
78. anthracene
79. benzo(ghi)perylene (1,12-benzoperylene)
80. fluorene
81. phenanthrene
82. dibenzo(a,h)anthracene(1,2,5,6-dibenzanthracene)
83. ideno(1,2,3-cd)pyrene(2,3-o-phenylenepyrene)
84. pyrene
85. *tetrachloroethylene
86. *toluene
87. *trichloroethylene
88. *vinyl chloride (chloroethylene)
pestidices and metabolites
89. *aldrin
90. *dieldrin
91. *chlordane(technical mixture & metabolites)
*DDT and metabolites
92. 4,4-DDT
93. 4,4-DDE(p,p-DDX)
94. 4,4-DDD(p,p-TDE)
*endosulfan and metabolites
95. a-endosulfan-Alpha
96. b-endosulfan-Beta
97. endosulfan sulfate
*endrin and metabolites
98. endrin
99. endrin aldehyde
*heptachlor and metabolites
100. heptachlor
101. heptachlor epoxide
*hexachlorocyclohexane (all isomers)
102. a-BHC-Alpha
103. b-BHC-Beta
104. r-BHC (lindane)-Gamma
105. g-BHC-Delta
*polychlorinated biphenyls (PCBs)
106. PCB-1242(Arochlor 1242)
107. PCB-1254(Arochlor 1254)
108. PCB-1221(Arochlor 1221)
109. PCB-1232(Arochlor 1232)
110. PCB-1248(Arochlor 1248)
111. PCB-1260(Arochlor 1260)
112. PCB-1016(Arochlor 1016)
113. *toxaphene
114. *antimony (total)
115. *arsenic (total)
116. *asbestos (fibrous)
117. *beryllium (total)
118. *cadmium (total)
119. *chromium (total)
120. *copper (total)
121. *cyanide (total)
122. *lead (total)
123. *mercury (total)
124. *nickel (total)
125. *selenium (total)
126. *silver (total)
127. *thallium (total)
128. *zinc (total)
129. **2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)

*Specific compounds and chemical classes as listed in the consent degree.

**This compound was specifically listed in the consent degree. Because of the extreme toxicity (TCDD), EPA recommends that laboratories not acquire analytical standard for this compound.

TOXIC SUBSTANCES IN THE GREAT LAKES

A CONVENIENT WAY TO DISCUSS TOXIC SUBSTANCES IN THE GREAT LAKES IS TO LOOK AT THE CLASSES AND SOURCES OF THE MATERIALS, THEIR DISTRIBUTION AND EFFECTS.

1. CLASSES

THE GENERAL CLASSES OF TOXIC SUBSTANCES THAT ARE PRESENTLY OF MAJOR CONCERN IN THE GREAT LAKES BASIN ARE (GLBC, 1978):

A. Halogenated organic compounds (cloro- and bromo-organics, including PCBs, PBBs, etc.)
B. Radioactive substances
C. Pesticides
D. Heavy metals and toxic non-metals (Hg - mercury, Pb - lead, As - arsenic)
E. Petroleum products
F. Miscellaneous compounds

2. SOURCES

THERE ARE MANY SOURCES FOR THE TOXIC SUBSTANCES THAT ENTER THE GREAT LAKES. THESE INCLUDE (GLBC, 1978):

A. Point sources (wastewater discharges from municipal and industrial effluents)
B. Non-point sources (land application of toxic materials followed by subsequent run-off from the land after heavy rains, snow melt, wind erosion, etc.; the atmosphere)
C. Urban runoff (Pb from automotive exhaust that deposited on streets, washed into storm sewers and eventually into receiving waters; grease and oil from automobiles; metals; lawn and garden pesticides)
D. Toxic and hazardous waste disposal sites or "phantom" disposal activities -- i.e., illegal dumping and spilling by a carrier to circumvent proper disposal regulations; ship and railroad spills
E. The atmosphere (can be considered a non-point source as in B. above but is also a major source itself; a source of PCBs, Pb, etc. to the Great Lakes as part of dry fallout or aerosols; poorly incinerated materials enter the atmosphere, as do volatiles released by industry)
F. Agricultural runoff (another significant source that can also be considered a non-point source)

3. DISTRIBUTION

THE DISTRIBUTION OF TOXIC SUBSTANCES IN THE GREAT LAKES BASIN IS NOW ONLY BEGINNING TO BE UNDERSTOOD AND IS TYPICALLY NOT VERY WELL DOCUMENTED. HOWEVER, CERTAIN PATTERNS HAVE BEEN IDENTIFIED CONCERNING THE DISTRIBUTION OF TOXIC SUBSTANCES IN THE WATER, SEDIMENTS AND FISH OF THE GREAT LAKES.

A. Water

The most complete compilation of historical data for toxic substances in Lake Michigan was published by Torrey (1976). No similar treatise has been found for the other Great Lakes and is a project that should be sponsored in the near future.

At one time, organochlorine pesticides, for example, were widely used in the Lake Michigan Basin and were applied to forest and agricultural lands and non-crop lands. Pesticides were also used in industry and for household pest control purposes. The extensive use of DDT and dieldrin in Wisconsin led to the transport of these chemicals to Lake Michigan via tributaries, land runoff and wastewater treatment facilities (LMIPC, 1972). Atmospheric precipitation was also implicated, perhaps due to the wind born transport of these pesticides following aerial spraying.

The concentration of pesticides in the waters of the Great Lakes is relatively low, due in part to the low solubility of these substances in water. Typical concentrations were generally below 1 ppb (part per billion; microgram per liter) and often near 1 ng/L (nanogram per liter) (Torrey, 1976). Detection of these very low concentrations is made possible by sensitive techniques such as gas chromatography. In addition to DDT and dieldrin, numerous other compounds that were detected by gas chromotography included PCBs, lindane, heptachlor, heptachlor eopxide, endrin, aldrin and methoxychlor. Much of the early DDT and dieldrin data from Lake Michigan and other waters prior to the late 1960's must be considered only approximate due to the likely interference of PCBs in the analysis of these pesticides. Thus, many pesticides were probably reported as present when in fact the gas chromatograph peaks were caused by PCBs.

Very little analytical work has been done on the presence of other trace organic compounds in the open waters of the Great Lakes. The biggest difficulty is the detection limits imposed by very minute concentrations of these materials. In order to solve such problems, large volumes of water will have to be extracted or passed through concentrating filters or resins in an attempt to get enough material to be able to perform an accurate analysis.

The concentrations of the main toxic inorganic materials (mercury, lead, arsenic) are quite low in Lake Michigan (Torrey, 1976). The inorganic substances do not appear to pose significant problems in Lake Michigan except for arsenic in Green Bay and lead in the southern basin.

B. Sediments

The sediments of the Great Lakes act as the ultimate sink for most of the toxic contaminants that enter the lakes. Some of the contaminants are biologically converted to more labile forms and are thus able to be remobilized. Mercury is a good example. In addition to biochemical conversion (methylation of mercury), certain other compounds such as PCBs are taken up by bottom organisms that either live or feed in the sediments and which are subsequently eaten by larger carnivores. This results in the eventual increase in concentration of the contaminant in carnivorous fish. Thus, despite the fact that the sediments are often hundreds of feet below the water surface, they do not always act as the ultimate sink for toxic substances.

The presence of many contaminants in the Great Lakes sediments was summarized by the PLUARG (1978) report. Of particular concern were mercury, lead and PCBs, resulting in considerably more data being available for these substances than for any other possible contaminants.

Contour maps showing the approximate distribution of mercury, lead and PCB concentrations in the Great Lakes sediments appear in Figures 1 through 3, respectively. Certain trends in the distribution of the contaminants can be inferred. The maps originally appeared in the PLUARG (1978) report.

The highest mercury concentrations generally appear in Lakes Erie, Ontario, and St. Clair. Previous industrial discharges and apparently present atmospheric deposition into and onto the Great Lakes and onto the land surface (with subsequent drainage to the lakes) appear to be the likely sources of mercury (PLUARG, 1978). Prior to 1970, a major mercury input to the lake system was the discharge of mercury into the St. Clair and Detroit Rivers. Based on the sediment patterns, Lake St. Clair appears to be a continuing source of mercury to Lake Erie despite the elimination of the chlor-alkali plant point source.

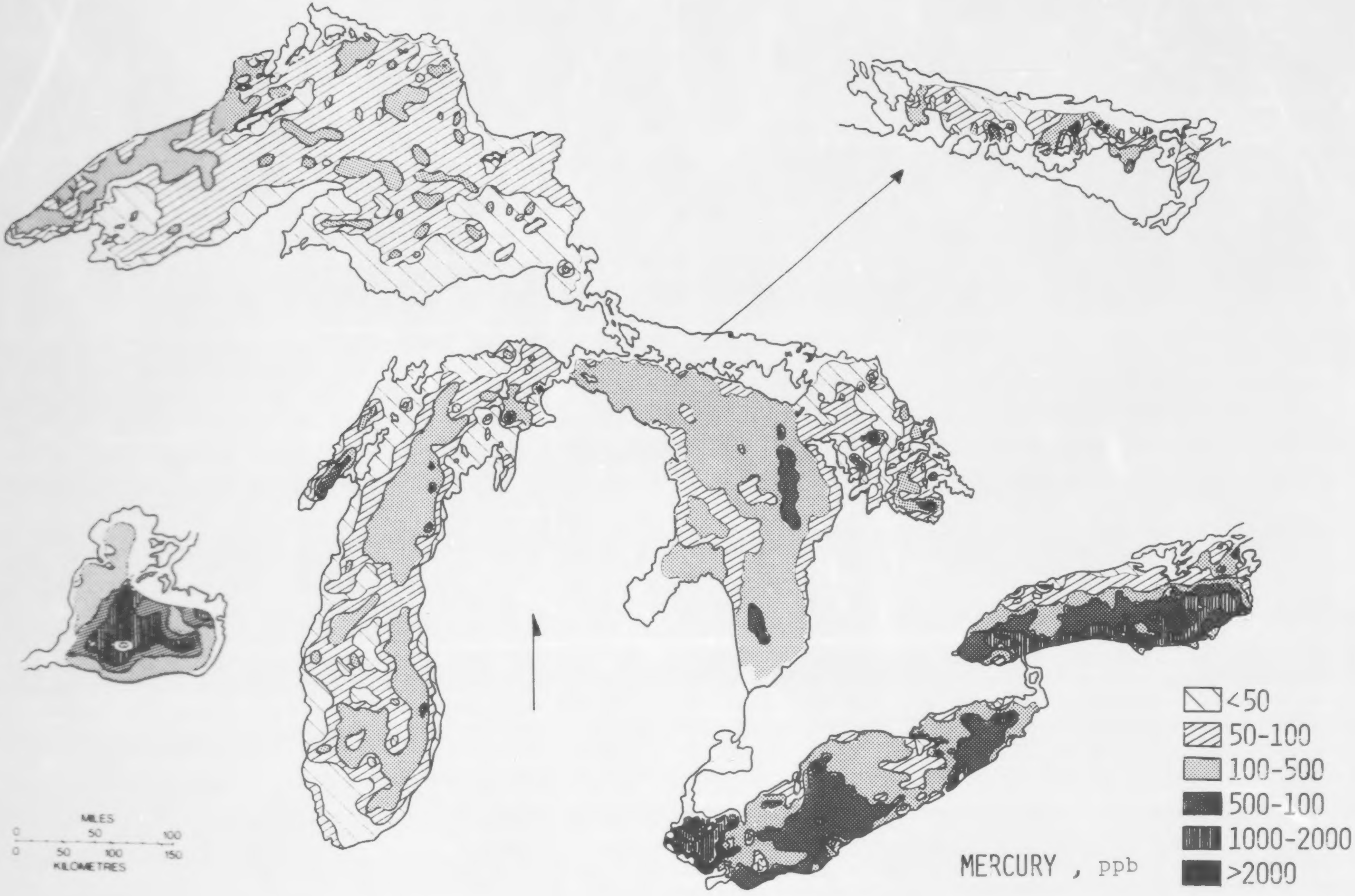
MILES
0
50
100
0
50
100
150
KILOMETRES
<50
50-100
100-500
500-100
1000-2000
>2000
MERCURY , ppb

FIGURE 1. MERCURY CONCENTRATIONS IN THE SURFACE SEDIMENTS OF THE GREAT LAKES (ppb = µg/kg) (PLUARG, 1978).

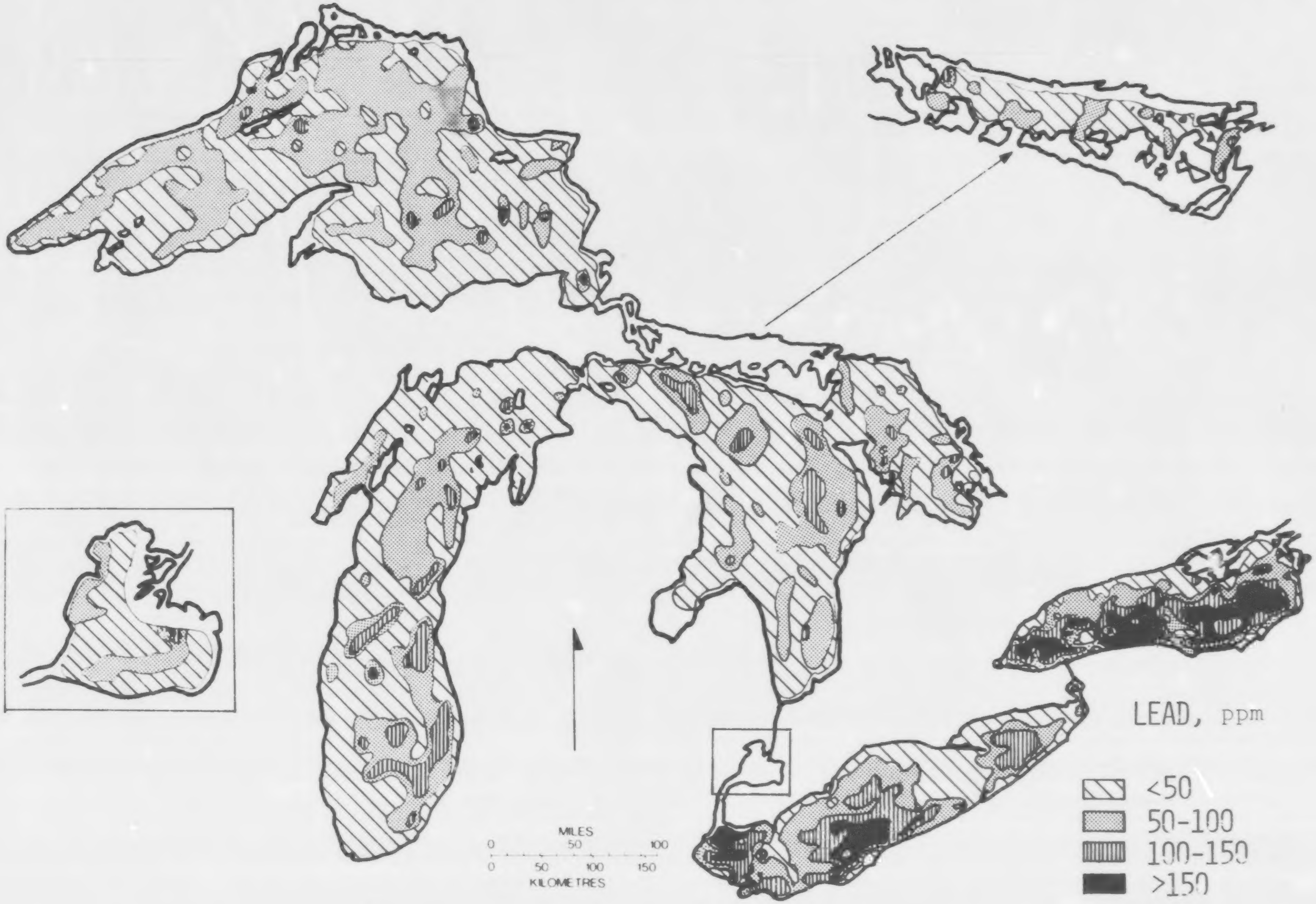
MILES
0
50
100
0
50
100
150
KILOMETRES
LEAD, ppm
▨ <50
▒ 50-100
▥ 100-150
■ >150

Figure 2. Lead concentrations in the surface sediments of the Great Lakes (ppm = mg/kg) (PLUARG, 1978).

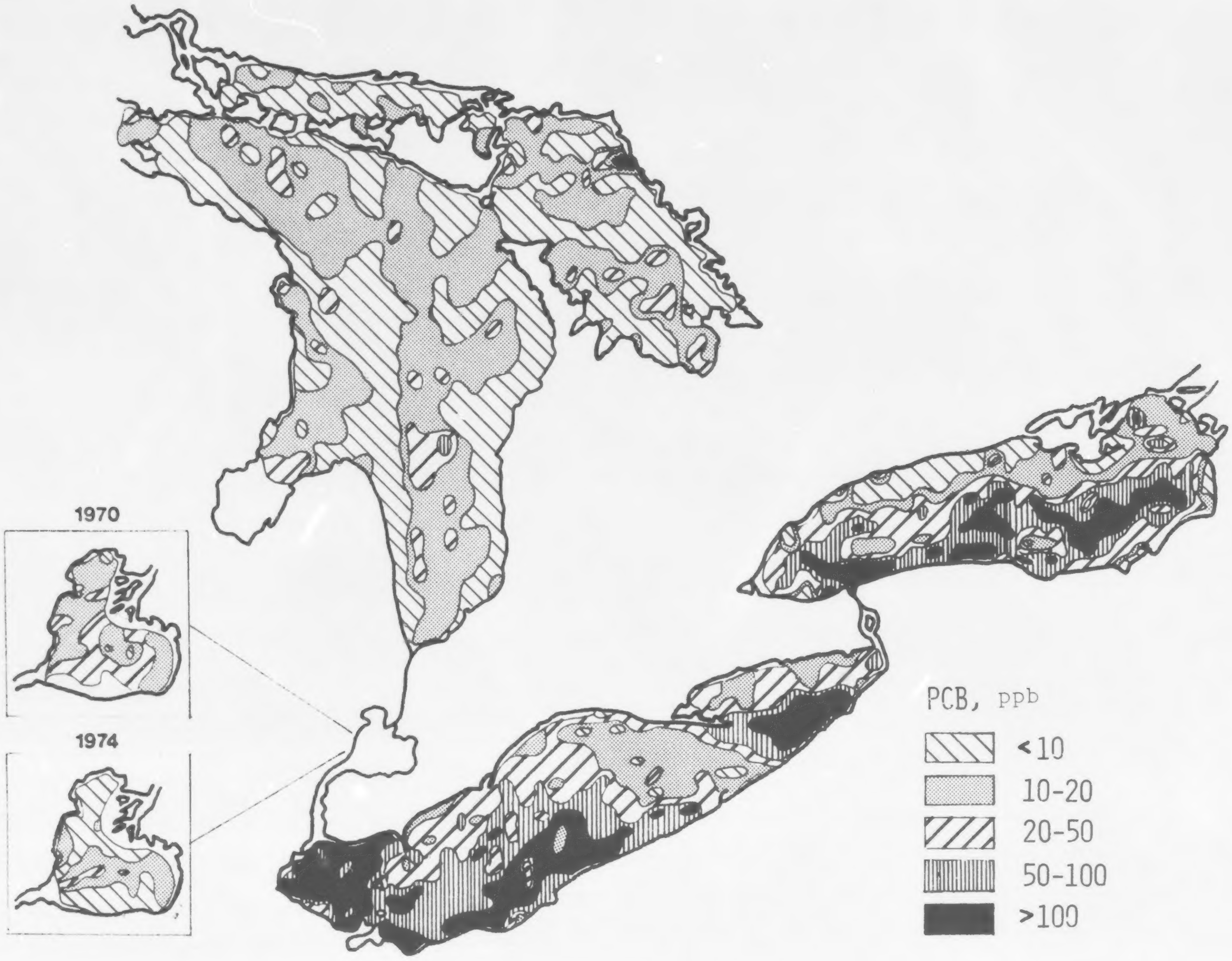
1970
1974
PCB, ppb
▧ <10
▩ 10-20
▨ 20-50
▥ 50-100
■ >100

FIGURE 3. PCB CONCENTRATIONS IN THE SURFACE SEDIMENTS OF LAKES HURON, ERIE AND ONTARIO (ppb = μg/kg) (PLUARG, 1978).

The transport of mercury enriched sediments from Lake St. Clair through the Detroit River and into western Lake Erie continues to be a problem. The resuspension of mercury contaminated sediments from western Lake Erie and the subsequent in-lake transport has carried mercury along the southern shoreline and led to its ultimate deposition in the eastern basin. The western basin of Lake Erie is an active area of sediment resuspension due to wind-induced wave action (WI Water Resources Center, 1978).

In Lake Ontario, mercury appears to be carried by the Niagra River with eventual dispersal throughout the eastern basin (PLUARG, 1978). The sharp decrease in point source inputs of mercury to the lakes should result in a gradual, long term decrease in the mercury content of the surface sediments. A major uncertainty in this prediction is the ability of mercury to be methylated by microorganisms -- i.e., converted to an organic form that is more easily taken up by higher organisms such as fish. The full impact of mercury methylation in the Great Lakes has not been estimated with any degree of certainty.

The distribution of lead in the sediments of the Great Lakes is not yet at the point of major concern. Lead has been reported to be capable of methylation (PLUARG, 1978), but this phenemenon has not been widely demonstrated in the lakes. The sedimentary distribution of lead (Figure 2) further illustrates the influence of urban areas on lead transport to the lakes. Urban areas adjacent to Lakes Erie and Ontario appear to be major problem sources, especially lead inputs from the Detroit River and the Cleveland, Ohio areas. The western and central basins of Lake Erie appear to be the most affected areas in the Great Lakes in terms of lead contamination. Isolated areas in the other lakes are affected to some degree but PLUARG (1978) did not consider these to be serious at present. The gradual decrease in lead in automobile fuel should alleviate the lead loading to the lakes and future inputs should decline roughly in proportion to the decreased concentration of lead in gasoline.

The concentrations of organic contaminants in Great Lakes sediments have not been completely mapped. Data for PCBs, however, have been compiled for Lakes Huron, Erie and Ontario (Figure 3). The contours indicate a general occurrence of PCBs in the sediments with higher loadings in the western and wouthern areas of Lake Erie and south central area of Lake Ontario. PLUARG (1978) estimated that non-point sources, including atmospheric inputs, account for the major inputs of PCBs to the lakes. Presently unpublished research indicates that PCBs are generally distributed throughout the sediments of Lakes Michigan and Superior but it is still too early to comment on the precise amounts present and possible trends and areas of concern.

C. Fish

In addition to the data mentioned earlier (Veith, 1973) concerning PCBs in Lake Michigan fish, PLUARG (1978) has recently summarized data for all of the Great Lakes (Table 2). It is clear that the most significant PCB contamination of fish occurs in Lake Michigan, at least based on the mean concentrations of all samples available in the data set.

One interesting aspect of the pesticide and PCB contamination of fish in Lake Michigan is the trend in concentrations that has developed over the past 5 to 8 years. There seems to be a slight decreasing trend but the eventual course of the trend can only be ascertained by further monitoring (Figures 4, 5 and 6). Furthermore, Olsson, et al. (1978) have urged caution when interpreting data such as those shown in Figures 4 through 6. The PCB concentrations in fish can vary from one season to another as well as during spawning season. Thus, fish monitoring programs must be conducted in a consistent manner to avoid bias in the interpretation of the data.

One reason that PCBs continue to appear in Lake Michigan fish in relatively high concentrations is that the chemical is easily bioaccumulated--i.e., passed through the food chain as

TABLE 2. SUMMARY OF PCB CONCENTRATIONS IN GREAT LAKES FISH (PLUARG, 1978).

Lake	Years of Sampling	Mean PCB Concentration All Samples (mg/kg)	Range (mg/kg)	Percentage of Major Species Exceeding Guidelines
Superior	1968-1975	0.61 (2.0)[a]	0.1-3.7	75% - whitefish (1974)-Marathon 20% - chub (1975)
Michigan	1972-1974	10.2 (5.0)	2.1-18.9	13% - chubs 50% - lake trout
Huron	1968-1976	0.82 (2.0)	0.1-7.0	50% - coho salmon (1971) 75% - rainbow trout (1974) - Douglas Point 33% - rainbow trout (1974) - Goderich 10% - rainbow trout (1974) - Nottawasaga River
Erie	1968-1976	0.88 (2.0)	0.1-9.3	27% of all samples analyzed had, in the range of concentrations for a sample, an upper PCB concentration 2 mg/kg. Of these, 75% were from the western and central basins. Species with the largest number of individuals exceeding the guideline were coho salmon, fresh-water drum, white bass and channel catfish.
Ontario	1972-1977	2.37 (2.0)	0.1-21.1	30% - carp (1972-74) 100% - coho salmon (1972-73) 27% - rock bass (1972-74) 88% - catfish (1972-74) 0% - sunfish (1972-74) 36% - white perch (1972-74) 42% - northern pike (1972-73) 0% - cisco 77% - smelt (1972-74) smelt, coho salmon and lake trout had PCB levels in whole fish ranging from 0.4-16.2 mg/kg. Mean concentrations in fish from the eastern basin were highest at 5.31 mg/kg (1977).

[a] (accepted guideline for fish)

smaller organisms are consumed by larger ones, ultimately reaching the primary carnivores in the lake (salmonids) which are highly prized sport fishery species. This process is illustrated in Figure 7.

The concentrations of mercury and lead in Great Lakes fish are provided in Table 3. Mercury still presents a problem since the concentrations ranges indicate that the US Food and Drug Administration (FDA) consumption guideline of 0.5 mg/kg has been, or is close to being exceeded in all of the lakes. Lead concentrations, on the other hand, are not yet very close to the recommended consumption advisory limit of 10 mg/kg. The main reason for this difference is likely due to the extensive amount of methylation of mercury occurring, as discussed earlier, in contrast to that for lead which is not well documented.

There is an encouraging trend occurring in the matter of mercury contamination of fish in western Lake Erie. Data collected from 1971 to 1977 indicate a gradually decreasing trend in the mercury content of white bass and yellow pickerel. Thus, it appears, at first glance, that when point sources of contaminants, such as mercury, are controlled, there is a recognizable response in the fish community. Continued monitoring must occur to document this trend, which is graphically illustrated in Figures 8 and 9.

285

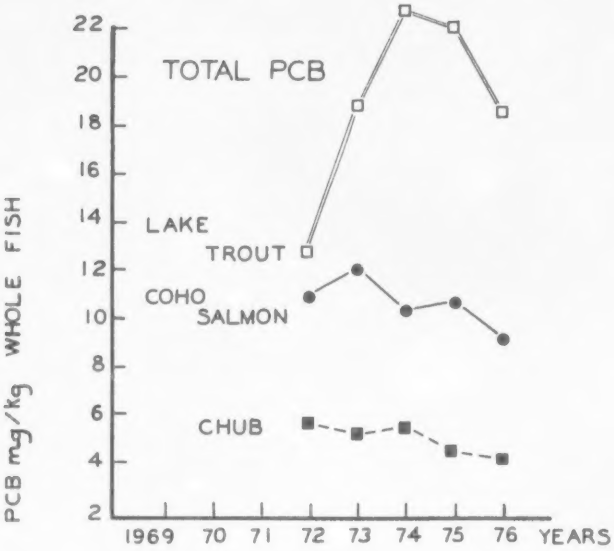

FIGURE 4. TOTAL PCB (MEAN CONCENTRATIONS) IN FISH FROM LAKE MICHIGAN (US FWS DATA AS CITED IN US EPA, REGION V, 1978).

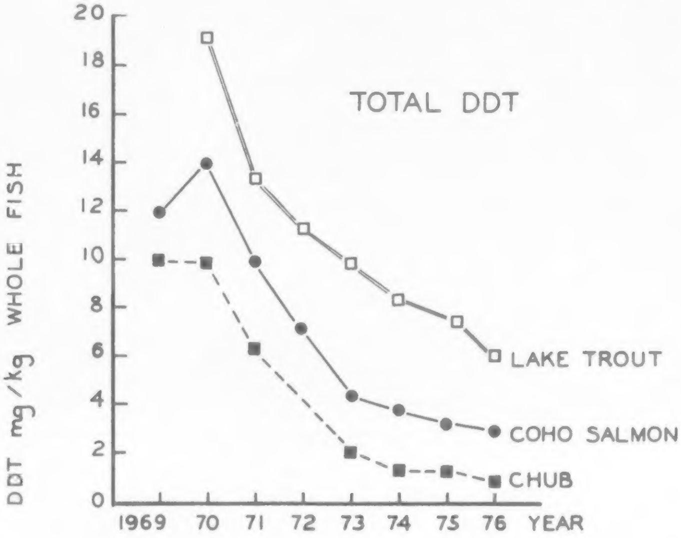

FIGURE 5. TOTAL DDT (MEAN CONCENTRATIONS) IN FISH FROM LAKE MICHIGAN (US FWS DATA AS CITED IN US EPA, REGION V, 1978).

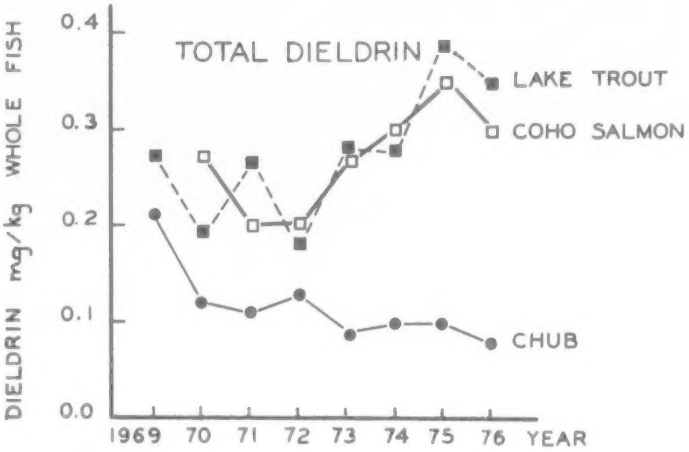

FIGURE 6. TOTAL DIELDRIN (MEAN CONCENTRATIONS) IN FISH FROM LAKE MICHIGAN (US FWS DATA AS CITED IN US EPA, REGION V, 1978).

Table 3. Concentrations of mercury (A) and lead (B) in Great Lakes fish (PLUARG, 1978).

(A) Mercury

Lake	Number of Fish Analyzed	Concentration[A] (mg/kg)
Superior	80	0.07 - 0.78
Michigan	20	0.22 - 0.54
Huron	50	0.60 - 0.18
St. Clair	742	0.06 - 3.8[B]
Erie	3000	0.03 - 1.52[C]
Ontario	85	0.06 - 0.49

[A] The accepted guideline concentration is 0.5 mg/kg

[B] From 50 to 100 percent of individuals in the 14 species analyzed in 1976 still exceeded the guideline

[C] Range of mean values

(B) Lead

Lake	Number of Fish Analyzed	Concentration[A] (mg/kg)
Superior	70	0.012 - 0.066
Michigan	23	N.D.[B] - 0.54
Huron	50	0.04 - 0.10
St. Clair	34	0.47 - 0.63[C]
Erie	49	0.04 - 0.12[C]
Ontario	219	1.0

[A] The accepted guideline concentration is 10 mg/kg.

[B] Not detected

[C] Range of mean values

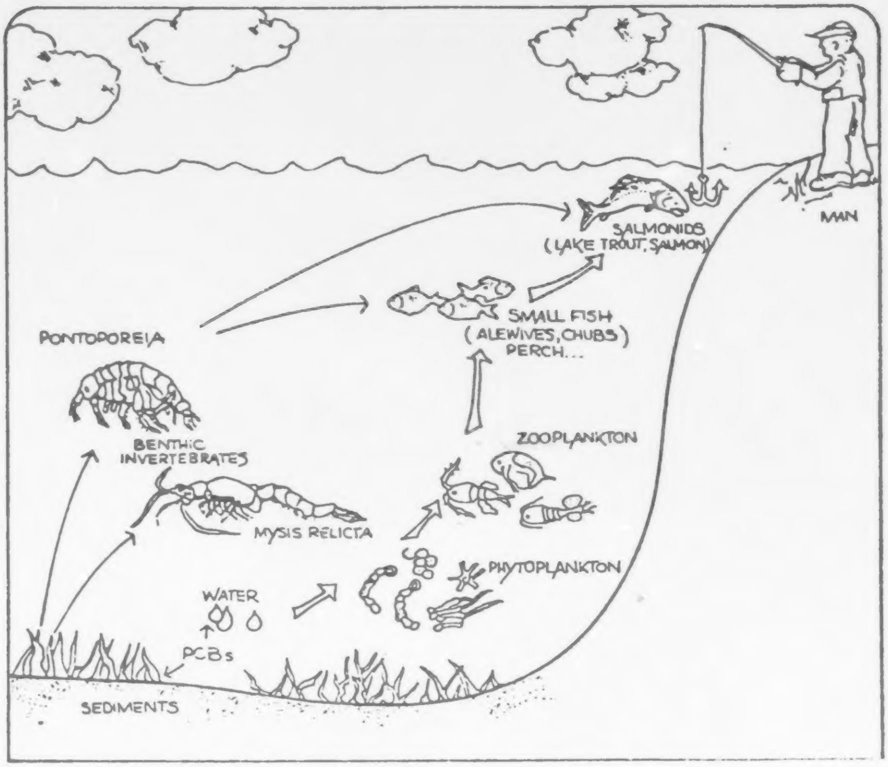
SALMONIDS
(LAKE TROUT, SALMON)
MAN
SMALL FISH
(ALEWIVES, CHUBS)
PERCH...
PONTOPOREIA
BENTHIC
INVERTEBRATES
MYSIS RELICTA
ZOOPLANKTON
PHYTOPLANKTON
WATER
PCBs
SEDIMENTS

FIGURE 7. THE PASSAGE OF PCBs THROUGH THE FOOD CHAIN IN LAKE MICHIGAN (WI SEA GRANT, 1976).

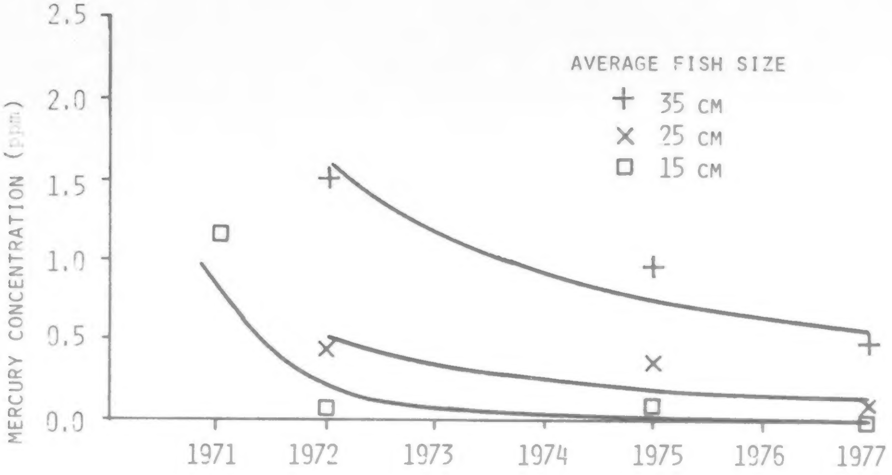

FIGURE 8. MERCURY CONCENTRATIONS IN WHITE BASS FROM WESTERN LAKE ERIE (WATER QUALITY BOARD, 1978).

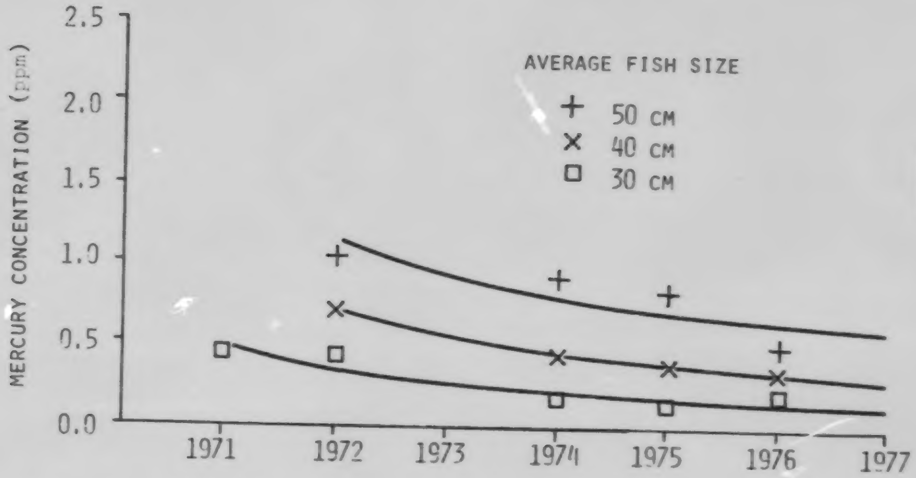

Figure 9. Mercury concentrations in yellow pickerel from western Lake Erie (Water Quality Board, 1978).

4. Effects

The overall effects of toxic substances in the Great Lakes have yet to be fully assessed. However, as just discussed in Section 3, it is clear that extensive contamination of the lakes has occurred.

One aspect which affects many citizens in the Great Lakes Basin, directly or indirectly, is the contamination of fish by PCBs. Most of the fish that are of sport fishery importance (e.g., salmonids) have PCB levels that exceed the FDA tolerance guideline of 5 ppm. However, there is no legal way to prevent sports fishermen from consuming their catch. Confounding this issue is the fact that no toxicological studies have conclusively linked the dietary intake of relatively low levels of PCBs with human health effects (PLUARG, 1978). Yet, despite the present lack of such evidence, there is documentation that the intake of PCBs at or near the FDA guideline significantly affects rhesus monkeys (Allen and Barsotti, 1976). These researchers showed that infants born to monkeys that were fed 2.5 to 5.0 ppm PCBs developed facial acne and edema; swelling of the eyelids; loss of facial hair including eyelashes; and hyperpigmentation of the skin. Half of the PCB-exposed infant monkeys died within eight months following birth, assumedly due to PCB intoxication (Allen and Barsotti, 1976). Surviving infant monkeys proved to be hyperactive in locomotor tests and to be deficient in learning various types of discrimination problems when compared to controls (Bowman _et al._, 1978).

The linkage of rhesus monkey health effects to potential human health problems is still in the speculative stage. However, the animal studies suggest that humans should limit their consumption of PCB-contaminated fish taken from the Great Lakes until epidemiological research determines the extent, if any, of low level dietary intake of PCBs on humans.

There have not been any widespread human health problems specifically related to the presence of mercury and lead in Great Lakes fish. However, it is possible that such problems may have occurred in the recent past based on the tragic experiences of people in Minamata, Japan who consumed mercury-contaminated seafood (Goldwater, 1971). Heavy consumers of fish from contaminated areas of the Great Lakes (particularly Lake St. Clair and western Lake Erie) may have experienced some symptoms of mercury poisoning.

In summary, the most serious effect of the presence of toxic substances in the Great Lakes is likely the diminished value of the Great Lakes as a natural resource, particularly in the area of production of fish that are suitable for human consumption. Commercial fishing activities have been seriously impaired while the sport fishing enthusiasts have had to be advised to limit their consumption of sport fish species to approximately one fish meal per week. Furthermore, the concern over other potentially toxic pollutants, e.g., asbestos in Lake Superior, has created problems for water utility officials. Those water utilities that draw their water supply directly from Lake Superior had to greatly improve their water treatment processes to reduce the levels of asbestos fibers present in the raw water in order to provide a margin of safety for consumers. The asbestos issue was not only a potential public health problem but also raised certain psychosocial issues as well. Lake Superior has always been considered one of the last frontiers of "pure water" in North America. The knowledge that this lake had potentially serious toxic substance problems was a rude awakening for many Americans.

Toxic Organic Compounds in Wisconsin Waters

In recent years, numerous toxic and potentially toxic organic substances have been identified in the waters of Wisconsin. The findings in Wisconsin are representative of experiences in the other Great Lakes states and will be discussed further in this section to provide an overview of some typical current problems.

Perhaps the best studied of the toxic organic compounds are the PCBs. These substances are ubiquitous in the Great Lakes environment and were the subject of a National Conference held in November, 1975 in Chicago, Illinois (US EPA, 1976). The PCB contamination problem has received at least as much attention in the technical literature and popular press as have DDT and mercury. Unlike these latter two contaminants, however - which appear to be abating - the PCB issue continues. Their unusual stability in the environment and capability of bioaccumulation have contributed to the fishery problems in Lake Michigan that were discussed earlier.

1. General Considerations

Contamination of Wisconsin waters by PCBs has been a matter of concern since the late 1960's (Kleinert, 1976). Fish collected from the Upper Mississippi River and also from Lake Michigan typically exceeded the FDA guidelines. The sources were found to be industrial and municipal effluents but, perhaps more significant, the atmosphere was implicated as a possible major contributor of PCBs, particularly to Lake Michigan (Kleinert, 1976). Kleinert attempted to perform a mass balance for PCBs entering the environment but met with limited success since many data points were missing or incomplete for the various environmental compartments (water, fish, sediment, etc.) that were considered. He also stated that the PCB problem in Wisconsin was chiefly a fishery problem (as opposed to a water supply problem, for example). A decreasing trend in the concentrations of PCBs in fish collected from the Upper Mississippi River was noted but was not similarly seen for those collected from Lake Michigan.

Thus it appears that either all of the point sources to Lake Michigan have not yet been fully controlled or else the non-point sources, especially the atmosphere, are of such a magnitude as to dwarf the effects of specific point discharges. The next section will help to explain why this dilemma still exists. There is considerable research presently underway in government and academic research laboratories in an attempt to better understand this situation (Delfino, 1976).

2. The Sheboygan River PCB Case

In March, 1978, very high concentrations of PCBs were reported for fish collected in the Sheboygan River in northeastern Wisconsin (Kleinert et al., 1978). The fish, originally collected in late 1977, showed PCB concentrations ranging from 26 to almost 1,000 ppm. As noted earlier, the FDA guideline is currently set at 5 ppm for fish collected from Lake Michigan and 2 ppm for the other Great Lakes (Table 2). Because of these very high concentrations, an intensive sampling program was instituted. The results verified the earlier findings--i.e., PCB concentrations in fish were significantly elevated above the values normally found in the Lake Michigan basin.

These findings indicated the probable existence of a previously unidentified point source of PCBs. Investigative work by the Wisconsin Department of Natural Resources quickly identified a metal casting plant as the source of the PCBs (Kleinert, *et al.*, 1978). The plant had been disposing of PCB-contaminated wastes behind its building and along a dike adjacent to the Sheboygan River. High water, runoff and erosion led to the deposition of the PCBs in the river sediments and through bioaccumulation, numerous fish species eventually became contaminated. The PCB-tainted dike material has been placed in sealed drums and awaits ultimate disposal when an approved toxic substances landfill can be located or developed.

The contaminated river sediments are still in place and can continue to contaminate fish and also be wasked out into Lake Michigan through normal stream sediment transport processes. The question of dredging the sediments has not been resolved since dredging might mobilize the PCBs and lead to more serious contamination of the lake. Furthermore, an adequate dredge spoil disposal site would have to be developed and such sites can only be placed on land or in contained shoreline areas - both of which are almost non-existent in the Great Lakes areas. The disposal of contaminated dredge spoils in the open waters of the State of Wisconsin is unlawful, posing the dilemma that both action and inaction will result in the same effect, that is more PCB contamination.

This case is an example of the type of toxic substance control problem that is likely to be discovered again and again in the future. The company involved in the Sheboygan River case had changed ownership since the period when PCBs were used in the hydraulic systems of the casting machinery. PCBs are no longer in use but the earlier careless disposal of the PCBs still haunts the present owners and the environment near the plant. It will continue to pose problems until all of the contaminated soil, dike material and river sediments are removed and secured.

There are likely other Sheboygan River cases waiting to be discovered, or in the event they are discovered, still awaiting decisions regarding clean-up (a good example is the Waukegan, Illinois harbor which is similarly contaminated with PCBs that were released by another manufacturing firm). These examples will help to fill in the missing pieces of the PCB materials balance that were still incomplete in 1975 (Kleinert, 1976). As these PCB sources are identified and eliminated, the uncertainty over the amount of PCBs entering Lake Michigan and the other Great Lakes will be reduced, leading to better estimates of the eventual recovery of the various systems from the effects of the contamination.

3. The Fox River Watershed

Probably the most industrialized drainage basin entering into Lake Michigan is the Fox River, a tributary to Green Bay in northeastern Wisconsin. The Lower Fox

River (from Lake Winnebago to Green Bay) is the site of numerous pulp and paper mills and receives their wastewaters as well as those from other industrial and numerous municipal facilities (Figure 10).

A study initiated in 1976 sought to identify the sources of PCBs and other chlorinated organic compounds in the Fox River (Peterman et al., 1978). Numerous organic and chlorinated organic compounds were identified in the wastewaters, river water and sediment and fish collected from the Fox River watershed. Included in these results were 20 of the priority pollutants that were earlier listed in Table 1. A comprehensive list of the compounds found in this study is given in Table 4 while quantitative data for certain other compounds identified are provided in Table 5.

It is clear from these data that the Fox River system receives a considerable amount of toxic or potentially toxic substances from a variety of sources. The heavy use of chlorine as a bleaching agent in pulp mill operations as well as the recycling of paper products contaminated with PCBs are likely sources of many of the chlorinated organic compounds.

The environmental significance and ultimate fate of these materials is not fully known at present except, of course, for the PCBs which are found in high concentrations in fish taken from the Lower Fox River. Future research activity, sponsored by state and federal agencies and the University of Wisconsin Sea Grant Program will help to resolve many of the present uncertainties.

4. Accumulation of PCBs by Lake Trout in Lake Michigan

The sources, distribution and effects of PCBs discharged to the Great Lakes, and Lake Michigan in particular, have been discussed earlier in this report. It is appropriate now to briefly outline the results of a recently completed study which significantly adds to our knowledge of how PCBs are taken up by salmonids (particularly lake trout) in Lake Michigan. This research was performed by Weininger (1978) who has also succinctly reviewed the PCB issue and provided a number of literature references which, for the sake of brevity, were not cited in this paper.

Weininger (1978) developed a general bioenergetic model to account for the accumulation of PCBs by Lake Michigan lake trout. With some modification, the model might apply to related species in the other lakes that have similar feeding habits and metabolic processes.

A schematic outlike of the PCB accumulation process in Lake Michigan was depicted earlier in Figure 7. Many of the processes shown in that figure rely on Weininger's work in which he showed that PCB uptake by lake trout was related to PCB concentrations in the food items consumer (a major input) as well as direct uptake (a minor

TABLE 4. COMPOUNDS IDENTIFIED BUT NOT QUANTIFIED IN SAMPLES FROM THE LOWER FOX RIVER SYSTEM (PETERMAN ET AL., 1978).

	Acetone, Tetrachloro-
c	Acetovanillone
	Aniline, Trichloro-
	Benzene, Dichloro-Diethyl-
	Benzoate, Dimethyl-
	Benzoate, Methyl-methoxy-
	Benzoic Acid
	Benzoic Acid, Isopropyl-
	Benzophenanthrene, Methyl- or (Benzanthracene, Methyl-)
	Benzophenone
c	Benzyl Alcohol
	Biphenyl
	Biphenyl, Methyl-
	Bisphenol A
	Bisphenol A, Chloro-
	Bisphenol A, Dichloro- (2 isomers)
	Bisphenol A, Tetrachloro-
	Bisphenol A, Trichloro-
	Borneol, Iso-
c	Caffeine
	Camphor, Oxo-
	Carbazole
a	Chlordane
a	DDD
a	DDE
a	DDT
c	Dodecane
	FATTY ACIDS AND THEIR METHYL ESTERS
c	Heptadecanoic Acid
c	Lauric Acid
b	Oleic Acid
c	Palmitic Acid
c	Stearic Acid
c	Methyl Palmitate
c	Methyl Stearate
c	Guaiacol
b	Guaiacol, Dichloro- (3 isomers)
	Heptadecane
a	Hexachlorocyclopentadiene
c	Hexadecane
	Indole, Chloro-
	p-Menth-4-ene-3-one
	Naphthalene, Isopropyl-
	Naphthalene, Methyl-
	Nonadecane
	Octadecane
c	Pentadecane
	Phenanthrene, Methyl-
a	Phenol
	Phenol, p-Tertiary Amyl-
a	Phenol, Chloro-
	Phenol, p-(- chloroethyl)-
	Phenol, Decyl-
c	Phenol, Ethyl-
	Phenol, Nonyl- (3 isomers)
	Phenol, Trichloro-dimethoxy-
	Phenol, Undecyl-
	Phenyl Decane
	Phenyl Dodecane
	Phenyl Undecane
	Phosphate, Tributyl-
	PHTHALATES
a	Dibutyl Phthalate
a	Diethyl Phthalate
a	Dioctyl Phthalate
c	Propan-2-one, 1-(4-hydroxy-3-methoxy phenyl) or guaiacyl acetone
	RESIN ACIDS
b	6,8,11,13-Abietatetraen-18-oic Acid
b	8,15-Isopimardien-18-oic Acid
b	Oxo-dehydroabietic Acid
b	Pimaric Acid
b	Sandaracopimaric Acid
	RESIN ACIDS, METHYL ESTERS
b	Methyl Dehydroabietate
b	Chlorodehydroabietic Acid (2 isomers)
b	Dichlorodehydroabietic Acid
	RESIN ACID METHYL ESTERS, CHLORINATED
	Methyl Chlorodehydroabietate
	Methyl Dichlorodehydroabietate
c	Salicyclic Acid
c	Syringaldehyde
	Syringaldehyde, Chloro-
	Tetradecane
	Toluene, Dichloro-
	Toluene, Trichloro-
c	Vanillin
c	Vanillic Acid
c	Veratrole, Dichloro-
c	Veratrole, Trichloro-
	Xylene, Dichloro-
	Xylene, Trichloro-

a Compounds on EPA Consent Decree Priority Pollutant List

b Compounds in paper mill wastewaters reported toxic to fish

c Other compounds previously reported in paper mill wastewaters

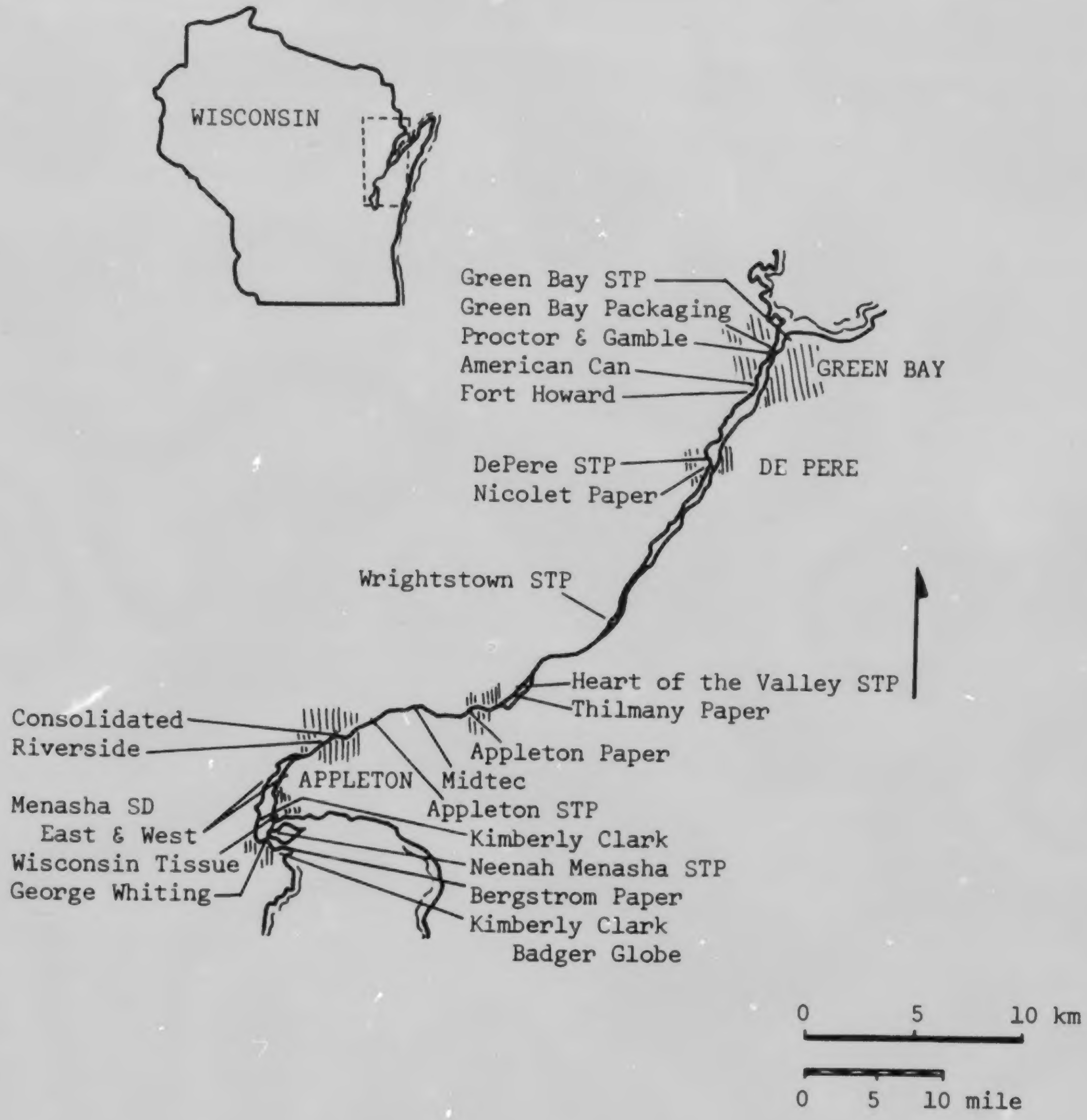
WISCONSIN
Green Bay STP
Green Bay Packaging
Proctor & Gamble
American Can
Fort Howard
GREEN BAY
DePere STP
Nicolet Paper
DE PERE
Wrightstown STP
Heart of the Valley STP
Thilmany Paper
Consolidated
Riverside
Appleton Paper
APPLETON
Midtec
Appleton STP
Menasha SD
East & West
Wisconsin Tissue
George Whiting
Kimberly Clark
Neenah Menasha STP
Bergstrom Paper
Kimberly Clark
Badger Globe
0
5
10 km
0
5
10 mile

FIGURE 10. EFFLUENT DISCHARGES TO THE LOWER FOX RIVER (PETERMAN ET AL., 1978).

INPUT) FROM THE WATER. AS SHOWN IN FIGURE 7, THE PRIMARY SOURCE OF PCBS ACCUMULATED IN LAKE MICHIGAN LAKE TROUT IS ADULT ALEWIVES.

OTHER FACTS IDENTIFIED BY WEININGER (1978) INCLUDE THE KNOWLEDGE THAT, FOR AN AVERAGE ADULT LAKE TROUT, THE PCB CONCENTRATION IS MORE RELATED TO ITS AGE THAN ITS SIZE, SIGNIFYING THAT ACCUMULATION IS MORE A FUNCTION OF TIME OF EXPOSURE THAN DIET COMPOSITION ALONE. ALSO, FASTER GROWING FISH ARE PREDICTED TO HAVE LOWER PCB CONCENTRATIONS THAN SLOWER GROWING FISH OF THE SAME WEIGHT BUT, SIGNIFICANTLY, LAKE TROUT PCB CONCENTRATION IS APPARENTLY INDEPENDENT OF FAT CONTENT. THUS, THE GENERALLY ACCEPTED CORRELATION OF PCB CONCENTRATION WITH FAT CONTENT MAY BE MORE FORTUITOUS RATHER THAN SIGNALLING A MECHANISM OF ACCUMULATION. THE ACCUMULATION OF HIGHER CONCENTRATIONS OF PCB IS RELATED TO THE LOWER GROSS ASSIMILATION CAPACITY OF A FATTY FISH AND NOT TO THE FACT THAT PCBS ARE MORE SOLUBLE IN FATTY TISSUE.

OF MAJOR IMPORTANCE IS WEININGER'S (1978) STATEMENT THAT GREATER THAN 50% OF THE PCBS IN ADULT LAKE MICHIGAN LAKE TROUT HAVE CYCLED THROUGH LAKE MICHIGAN SEDIMENTS. THIS EMPHASIZES THE FOOD CHAIN IMPLICATIONS SHOWN IN FIGURE 7, SINCE BENTHIC INVERTEBRATES ARE EATEN BY ADULT ALEWIVES WHO IN TURN ARE CONSUMED BY ADULT LAKE TROUT.

THUS, IN ORDER TO REDUCE FUTURE CONCENTRATIONS OF PCBS IN LAKE TROUT, THE PCB CONTENT OF THE ALEWIVES MUST BE REDUCED. WEININGER SPECULATED THAT IF THE ALEWIFE POPULATION COULD BE REDUCED (BY INTENSIVE HARVESTING?), THEN LAKE TROUT WOULD SWITCH TO SMELT AS A PRIMARY FOOD SOURCE. SMELT HAVE MUCH LOWER PCB CONCENTRATIONS WITH THE RESULT THAT LAKE TROUT PCB LEVELS SHOULD RAPIDLY DECREASE, PERHAPS TO AS MUCH AS ONE-THIRD OF PRESENT LEVELS. THIS COULD RESULT IN THE LAKE TROUT EVENTUALLY MEETING THE CURRENT FDA COMMERCIAL SALE LIMIT OF 5 PPM. WEININGER'S HYPOTHESIS IS INTRIGUING AND FISH RESOURCE MANAGERS HAVE NOW BEEN CHALLENGED TO TAKE INNOVATIVE STEPS TO REDUCE THE PCB CONTENT OF A PRIZED LAKE MICHIGAN RESOURCE, THE LAKE TROUT. GRANTED, THE FISHERY IS SOMEWHAT ARTIFICIAL AT PRESENT, DUE TO THE INABILITY OF THE SALMONIDS TO SUCCESSFULLY REPRODUCE IN THE SYSTEM, BUT AS LONG AS SALMONIDS ARE STOCKED, SOCIETY SHOULD BE ABLE TO TAKE ADVANTAGE OF THE OPPORTUNITY TO REDUCE THE LEVEL OF CONTAMINATION TO ACCEPTABLE LIMITS.

CONTROL OF TOXIC SUBSTANCE CONTAMINATION IN THE GREAT LAKES BASIN

RESOURCE MANAGEMENT STRATEGIES IN THE GREAT LAKES BASIN MUST CONTEND WITH THE TOXIC SUBSTANCES ISSUE. THIS ISSUE INVOLVES HUMAN AND ENVIRONMENTAL HEALTH, THEREBY ELEVATING ITSELF TO A POSITION OF PROMINENCE ABOVE SOME OF THE EARLIER GREAT LAKES PROBLEM ISSUES SUCH AS EUTROPHICATION AND THERMAL POLLUTION. THE TASK WILL NOT BE EASY BECAUSE IT REQUIRES RESOURCE MANAGERS TO ADOPT NON-TRADITIONAL CONCEPTS BUT, BY CONSIDERING THE FOLLOWING FACTS, IT WILL BE CLEAR THAT PROGRESS CAN AND MUST BE MADE:

*a number of toxic substances are already present in the Great Lakes

*some toxic pollutants in the Great Lakes are derived from sources well removed from the Basin and are carried hundreds of kilometers by atmospheric processes, illustrating the need for national and international cooperation

*the national goal of zero discharge of toxic substances into natural waters must be vigorously pursued, particularly in the Great Lakes Basin

*methods must be sought for the attenuation or removal of those toxic substances already present in the Great Lakes Basin

*existing laws in the United States and Canada must be vigorously enforced to reduce and ultimately eliminate the discharge of toxic substances to the aquatic environment, including the Great Lakes and its tributaries

A toxic control plan for the Great Lakes Basin has recently been developed and is now available in draft form (GLBD, 1978b). The plan draws on numerous sources for its background information, including publications and policies of the International Joint Commission and its Pollution from Land Use Activities Reference Group (PLUARG, 1978) and also the US Environmental Protection Agency. Some of the important cornerstones of the Great Lakes Basin Commission plan are the many existing environmentally related laws, sections of which can be cited in the effort to control toxic substance contamination in the Great Lakes Basin. For convenience, these laws have been listed under three general categories (GLBC, 1978):

1. Laws Regulating Toxic Substances Themselves
    - A. Toxic Substances Control Act
    - B. Federal Insecticide, Fungicide and Rodenticide Act
2. Laws Regulating the Sources of Toxic Substances
    - A. Federal Water Pollution Control Act, 1972 Amendments
    - B. Federal Water Pollution Control Act, 1977 Amendments
    - C. Resource Conservation and Recovery Act
    - D. Clean Air Act
    - E. Hazardous Materials Transportation Act
    - F. Ports and Waterways Safety Act
    - G. 1.B. above
3. Laws Concerned with Effects of Toxic Substance Contamination
    - A. Safe Drinking Water Act
    - B. Food, Drug and Cosmetic Act
    - C. 2.A., 2.B. and 2.C. above

Despite the laws that have been enacted to control pollution, contamination of the Great Lakes by toxic substances continues. Numerous examples have been cited in this report; others not discussed here (see, for example, Kaiser, 1978) but also of equal importance, indicate the need for continued concern and cooperation on the part of those who produce, use and discharge toxic substances. When cooperation is not forthcoming or is insufficient - as is the situation all too often - aggressive enforcement of the law must be

Pursued by state and federal regulatory agencies. Thus, in spite of certain corporate public relations pronouncements to the contrary, regulatory surveillance and enforcement will be one of the major stimuli in controlling the release of toxic substances in the Great Lakes Basin.

In addition to surveillance, increased emphasis must also be placed on research and development. During the course of the analysis of environmental samples, numerous unknowns still appear (see for example, Peterman et al., 1978). Resources must be made available to governmental and university researchers so that they can reduce the number of these environmental "unknowns" and thereby decrease the number of incidents that were at one time euphemistically referred to as "pollutants of the month".

It is known that a number of toxic substances are transported to the Great Lakes Basin from other areas of the United States and Canada (see, for example, Delfino, 1976). This emphasizes the need for resource managers to know considerably more about atmospheric chemical transport and reaction phenomena. Atmospheric pollution chemistry is now receiving research attention in some Great Lakes area universities (Drs. A. Andren at Wisconsin-Madison; S. Eisenreich at Minnesota-Minneapolis; T. Murphy at DePaul; and H. Sievering at Governors State). More can and must be done, since even if point source discharges are completely eliminated within the Basin, those that continue unabated elsewhere will still affect the Great Lakes to a certain extent.

The Great Lakes states and the US EPA should agree upon a common list of priority pollutants that will receive primary emphasis for monitoring and control in the Basin. Perhaps the Flannery Decision list (Table 1) will be a useful starting point.

The Great Lakes Basin Commission (GLBD, 1978b) sees federal and state cooperation as being critical in an effort to control toxic substance contamination in the Great Lakes. Furthermore, these governments should insist that laboratory facilities be upgraded to enable timely, accurate and precise measurements of toxic substances to be made. The governments must also be willing to provide funds for this important activity even during a period when budgetary restraints are receiving top priority in the minds of political leaders. Research is also needed to determine the human health implication and environmental significance of those toxic substances that have been found to be important in the Great Lakes Basin.

A recent PLUARG report the the International Joint Commission (PLUARG, 1978) sums up the toxic substances control issue very well and the following points are excerpted from that document:

In order to control toxic substances and to reduce their inputs to the Great Lakes

*toxic substances must be controlled at their source *closer cooperation between the United States and Canada in implementing toxic substances control legislation must occur

*proper management control and the means of ultimate disposal of toxic substances presently in use must be developed

*identification and monitoring of historic and existing solid waste disposal sites (where there is an existing or potential discharge of toxic substance) must be done and control programs at those sites must be executed as needed

*joint United States - Canadian expansion of efforts to assess the cumulative and synergistic effects of increasing loads of toxic contaminants on environmental health must be given high priority

*the rapid translation of these assessments into revised water quality objectives must be made; for certain toxic substances, a zero loading to the Great Lakes will be necessary

In addition to the PLUARG (1978) concerns, another major point of interest involves the analytical detection of miniscule concentrations of compounds which were not previously anticipated in the Great Lakes Basin. Should governments then regulate (control) these substances "just because they are there", or do we await appropriate toxicity testing to determine their potential environmental and human health impact? It is a question that is central to the environmental control policies of state and federal agencies and its resolution can have extremely significant impacts (economic and societal) if improperly implemented.

To summarize this report, it should now be clear to the reader that there are still significant toxic substance problems in the Great Lakes Basin and that steps are being taken to resolve the most serious ones. Continued societal concern, interest and support must be sustained to enable regulatory agencies to solve all of the remaining toxic substance problems. This will take considerable time and money but for the more than 15 percent of the total United States population that lives in the Great Lakes Basin, these investments now will provide long term dividends in terms of improved water quality and enhanced utilization of the Great Lakes natural resources.

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Paul is extremely busy with professional conferences in outdoor education and prairie ecology. In the fall of 1976, he participated in the Illinois Natural Area Inventory which took him into numerous old cemeteries south of Chicago in search of prairie remnants. He has also been active in environmental groups that are striving to preserve land. He is president of the Sand Ridge Audobon Society and a member of the Save The Dunes Council in Northwest Indiana, the Nature Conservancy and the Ridges Sanctuary Association.

In his spare time, he enjoys reading and photography.

GLOSSARY

ASSOCIATION: A climax plant community identified by a combination of dominant species present.

BIOME: A major geographic division of ecological communities based on plants and animals present.

BOREAL: Typical of cold northern climates as in boreal spruce-fir forest.

CONIFEROUS: Trees which are needle-leaved evergreen (except for larch) in the Lake Michigan area and which become more abundant toward the northern part of the basin.

DECIDUOUS: Among trees and shrubs having foliage that is shed during the summer. Deciduous trees are also known as hardwoods.

EUTROPHIC: As with lakes, having a high level of nutrients. Naturally eutrophic lakes are generally warm and shallow with a dense growth of aquatic plants.

EUTROPHICATION: The process by which a lake becomes more eutrophic. If continued, it becomes a swamp. This process takes two forms--natural and cultural.

EUTROPHICATION, CULTURAL: The natural eutrophical process artifically accelerated by man's interference both by increased flow of sediment and by increased plant growth, especially blue-green algae, through fertilization by sewage and phosphate detergents.

EUTROPHICATION, NATURAL: A gradual filling-in of lakes caused by sediment from surrounding lands and the growth and decay of aquatic plant life.

FORBS: In a prairie community those plants which are not grasses. Forbs include both colorful wildflowers and other less showy plants.

FOREDUNE: The dune ridge closest to the lakeshore and generally covered with grass and scattered shrubs.

FOREST, NORTHERN MIXED: A general grouping of forests characteristic of the northern part of the Lake Michigan basin and composed of a mixture of coniferous and deciduous trees.

FOREST, TEMPERATE DECIDUOUS: A forest composed of trees that lose their leaves during the cold season and then regenerate their leaves during the warm season.

INDICATOR SPECIES: Plants and animals which are characteristic of a certain ecological community.

MESIC: Forests and prairies which grow under optimum soil and moisture conditions that are neither too wet nor too dry. Mesic prairies have particular indicator plants and have a greater diversity of species than those wetter or drier. Mesic forests also have their indicator plants and are shadier than wetter or drier forests.

OLIGOTROPHIC: Characteristic of a lake that is low in nutrients. Such lakes are generally cold, deep and have few aquatic plants.

PANNE: A marsh or pond formed in a wind-sculptured depression or blowout in the dunes along a coastline. Due to the leaching of calcarious (containing calcium) minerals from the surrounding dunes, the area may support rare and specialized species of plants.

SAVANNA: An ecological community consisting of a mixture of panne plants with scattered trees.

SEDGES: Plants similar to grasses in appearance but having a stem triangular in cross section rather than flattened or rounded. Sedges also bear a different type of fruit than grasses.

SPHAGNUM: A type of moss found in acid soil bogs.

SUCCESSION: The natural progression of vegetational types on the same area of land over a period of time. Succession occurs in two forms--primary and secondary succession.

SUCCESSION, PRIMARY: Occurring on an area that has had no previous vegetation such as on newly formed sand dunes, mud flats, or bare rock.

SUCCESSION, SECONDARY: Occurring in an area where the original vegetation had been destroyed by fire or cutting.

XERIC: Having very dry conditions.

PRESERVATION OF NATURAL SYSTEMS OF LAKE MICHIGAN AND THE COASTAL REGION COMMUNITIES

THIS CHAPTER WILL EXPLORE THE NATURAL ECOLOGICAL COMMUNITIES (PLANT AND ANIMAL COMMUNITIES) OF LAKE MICHIGAN AND ITS SHORELINES, AS WELL AS WHAT IS BEING DONE TO PRESERVE AND MAINTAIN THESE SYSTEMS. INCLUDED WILL BE A DISCUSSION OF ORIGINAL NATURAL COMMUNITIES, FISH POPULATIONS AND ENDANGERED SPECIES.

LAKE MICHIGAN IS UNIQUE IN SEVERAL WAYS. IT EXTENDS FURTHER SOUTH THAN ANY OF THE LARGE OLIGOTROPHIC LAKES IN THE NORTHERN HEMISPHERE AND YET SINCE IT EXTENDS TO A GREAT DISTANCE NORTH AND SOUTH, IT HAS THE GREATEST VARIETY OF ECOLOGICAL COMMUNITIES ALONG ITS SHORELINE. BOTH OF THESE FACTS ARE TRUE DESPITE THE CHANGES WROUGHT BY MAN WITHIN THE LAST TWO-HUNDRED YEARS.

AN OLIGOTROPHIC LAKE IS BY DEFINITION A DEEP COLD BODY OF WATER THAT IS LOW IN NUTRIENTS AND GENERALLY SUPPORTS "COLD WATER" FISHES--TROUT, SALMON, AND BURBOT. THE OPPOSITE WOULD BE A EUTROPHIC LAKE--ONE THAT IS WARM, OFTEN SHALLOW, HAS A RIGH CONCENTRATION OF NUTRIENTS AND IS INHABITED BY WARM WATER FISHES--PERCH, CARP, LARGEMOUTH BASS AND BLUEGILLS. WHILE THE TENDENCY IS FOR OLIGOTROPHIC LAKES TO BE CONVERTED TO EUTROPHIC LAKES BY NATURAL AGING, THIS PROCESS IS GREATLY ACCELERATED BY MAN'S POLLUTING INFLUENCES--THE PROCESS BEING CALLED "CULTURAL EUTROPHICATION." ALTHOUGH THIS PROCESS WILL BE COVERED IN OTHER CHAPTERS, THIS CHAPTER WILL DISCUSS THE EFFECT OF EUTROPHICATION ON THE FISH COMMUNITY.

DURING THE ICE AGE, CONTINENTAL GLACIERS NORTH OF THE FORTIETH PARALLEL FORMED A LARGE NUMBER OF OLIGOTROPHIC LAKES, MOST OF THEM BY THE SIMPLE PROCESS OF ROCK-FILLED ICE SCOURING THE BEDROCK. THE LAKES THIS FORMED INCLUDE GREAT BEAR AND GREAT SLAVE LAKES OF NORTHERN CANADA, LAKE BAIKAL IN SIBERIAN RUSSIA AND LOCK NESS IN SCOTLAND. ALL OF THESE LAKES SHARE WITH LAKE MICHIGAN THE POPULATION OF VARIOUS COLD WATER FISHES, ESPECIALLY THE SALMONOIDS WHICH INCLUDE THE WHITEFISH, TROUT AND SALMON. SINCE LAKE MICHIGAN EXTENDS THE FURTHEST SOUTH, AND ALSO THIS LOWER END BEING HIGHLY URBANIZED, IT WOULD BE EXPECTED THAT THIS LAKE WOULD BE THE MOST SUBJECT TO BOTH NATURAL AND CULTURAL EUTROFICATION. THE EFFECT OF SUCH ARTIFICIAL CHANGE ON LAKE MICHIGAN FISH POPULATIONS WILL BE DISCUSSED LATER IN THE CHAPTER.

THE DIVERSITY OF ECOLOGICAL COMMUNITIES AS SEEN IN THE VEGETATIONAL TYPES OF THE LAKE MICHIGAN SHORELINE IS A FEATURE NOT CHARACTERISTIC OF THE OTHER OLIGOTROPHIC LAKES FARTHER NORTH. LAKE MICHIGAN IS UNIQUE AMONG THE GREAT LAKES IN INCLUDING THREE DIFFERENT BIOMES

ALONG ITS SHORELINE--TALL-GRASS PRAIRIE, TEMPERATE DECIDUOUS (HARDWOOD) FOREST, AND NORTHERN MIXED FOREST (INCLUDING BOTH HARDWOOD AND CONIFER TREES). THERE ARE A NUMBER OF INTERPRETATIONS OF THESE COMMUNITIES AS WELL. SUCH A DIVERSITY IS POSSIBLE BECAUSE OF THE NORTH-SOUTH ALIGNMENT OF THE LAKE WHICH EXTENDS OVER A DISTANCE OF 320 MILES AND THE FACT THAT LAKE MICHIGAN IS LOCATED FURTHER WEST THAN LAKE HURON, ERIE, OR ONTARIO, PUTTING IT AT THE EASTERN EDGE OF THE PRAIRIE BIOME.

ANOTHER UNIQUE FEATURE OF LAKE MICHIGAN IS THE DIVERSE EXAMPLES OF ECOLOGICAL SUCCESSION ALONG THE SHORELINE, ESPECIALLY IN SAND DUNES. MUCH EARLY STUDY WAS MADE OF THE DUNES ALONG THE SOUTHERN END OF THE LAKE, SOME OF WHICH LED TO A MUCH BROADER APPLICATION WHICH HAS PLAYED AN IMPORTANT PART IN THE MODERN SCIENCE OF ECOLOGY. MANY COLLEGE LEVEL CLASSES STILL MAKE USE OF THE DUNES AS A STUDY AREA DESPITE THE CHANGES DUE BY URBANIZATION THAT HAVE OCCURRED SINCE THE ERA OF THE EARLY ECOLOGISTS.

TODAY THE PROTECTION OF LAKE MICHIGAN AND ITS SHORELINE HAS REACHED A CRITICAL LEVEL BECAUSE OF THE EFFECTS OF POLLUTION, URBANIZATION AND RECREATIONAL PRESSURES. ALTHOUGH THIS PROBLEM IS GENERALLY KNOWN, THE PUBLIC IS RELATIVELY UNAWARE OF THE SPECIFIC FEATURES OF THE LAKE MICHIGAN ECOSYSTEM THAT ARE THREATENED.

NATURAL AREAS ARE CLASSIFIED UNDER COMMUNITY TYPES AND COMMUNITY SUBTYPES WITH EACH ONE BASED ON A CERTAIN SET OF CRITERIA. DIVISION INTO THE MAIN HEADINGS IS BASED ON DOMINANT CHARACTERISTICS, I.E., FOREST, PRAIRIE, SAVANNA, AQUATIC AND PRIMARY. THE LATTER CATEGORY IS DEFINED AS PLANT SUCCESSION ON PREVIOUSLY BARE AND NEWLY FORMED SURFACES WHICH HAVE NEVER SUPPORTED VEGETATION BEFORE. THIS IS THE OPPOSITE OF SECONDARY SUCCESSION WHICH IS ANOTHER TERM FOR SECOND GROWTH THAT OCCURS AFTER LUMBERING, FIRE OR TORNADO.

COMMUNITY SUBTYPES ARE BASED ON CLIMATIC DIFFERENCES IN THE CASE OF THE FORESTS. ALL OTHERS ARE THE BASIC SUBSTRATE TYPE. THE NATURAL COMMUNITIES REPRESENT A FURTHER SUBCLASS BASED ON MOISTURE AND OTHER FACTORS. THIS CLASSIFICATION HAS BEEN SIMPLIFIED RATHER ARBITRARILY TO INCLUDE ONLY THOSE COMMUNITIES FOUND IN THE LAKE MICHIGAN VICINITY. IN ADDITION THERE ARE SOME LOCALIZED INTERGRADES AND VARIATIONS ON THOSE CATEGORIES THAT ARE INCLUDED. A STUDY OF THESE DIFFERENT COMMUNITIES SHOULD STRONGLY REFUTE THE ARGUMENT MADE BY THE UNINFORMED "YOU'VE SEEN ONE DUNE (OR PRAIRIE, FOREST OR MARSH) AND YOU'VE SEEN THEM ALL".

ALONG WITH THE DESCRIPTIVE OUTLINES OF DIFFERENT VEGETATIONAL TYPES, THERE IS ALSO DATA ON SIGNIFICANT ANIMAL LIFE, INCLUDING ANY ENDANGERED SPECIES WHICH ARE ASSOCIATED WITH A PARTICULAR COMMUNITY. ENDANGERED SPECIES AS USED HERE IS A RELATIVE TERM AND IS NOT SOLELY LIMITED TO THE FEDERAL LISTING. SEVERAL STATES HAVE THEIR OWN ENDANGERED SPECIES LIST, AND THERE IS ANOTHER CATEGORY CALLED "THREATENED SPECIES" WHICH ARE LIKELY

TO BECOME ENDANGERED. ALSO INCLUDED IS A LISTING OF THE VARIOUS TYPES OF MAN-CAUSED THREATS AFFECTING EACH COMMUNITY. ALTHOUGH DEVELOPMENT RELATED TO POPULATION PRESSURE AND TECHNOLOGY HAS AFFECTED EVEN THE MOST REMOTE PORTIONS OF THE LAKE MICHIGAN AREA, CERTAIN ECOLOGICAL COMMUNITIES ARE AFFECTED BY SPECIFIC TYPES OF PRESSURES.

I. FOREST--NATURAL COMMUNITY WHERE TREES FORM MORE THAN 80% CANOPY COVER WITH AN UNDERSTORY OF SAPLINGS, SHRUBS AND HERBACEOUS PLANTS.

A. NORTHERN TYPES--These include many of the forests in the northern half of the Lake Michigan basin and generally have a varying proportion of conifers present. These forests bear geographical relationships with the forests of Canada and the rest of the northern lake states and are what the public considers the north woods.

1. NORTHERN DRY FOREST--This is usually found on sandy soils and is more prevalent close to Lake Michigan on the Michigan side than on the Wisconsin side. Much of this forest along with the northern drymesic forest (see the next category) was cut over heavily during the logging era of the late 19th and early 20th centuries. Fire is a very significant factor in this community with jack pine actually being dependent on fire to open their cones and set their seed. Although the parent trees may be destroyed, a dense stand of seedlings will result. Without fire they will eventually be replaced by other tree species. In sand dunes near the lakeshore the jack and white pine extend much further south than they do inland, with some small scattered groves still present in the Indiana Dunes near Gary.

   a. DOMINANTS--jack pine, red pine, white pine, Hills' Oak, quaking aspen
   b. GROUNDLAYER--lowbush blueberry, trailing arbutus, wintergreen, pipsissewa
   c. TYPICAL ANIMAL LIFE--red squirrel, red-backed mouse, least chipmunk, Canada jay, red-breasted nuthatch, pine warbler
   d. ENDANGERED SPECIES--none close to Lake Michigan, although the Kirtland's warbler, which nests in jack pines, is found further east of the Lake and no where else in the world
   e. THREATS--although there are some pine groves protected in state parks and national forests, more intensive recreational use, especially by off-road vehicles, could threaten some of these.
   f. EXAMPLES--Wisconsin: none near Lake Michigan; Illinois: No examples survive; Indiana: scattered patches of jack pine forest are found in the Indiana Dunes State Park and the National Lakeshore; Michigan: Ludington State Park, Muskegon State Park and Manistee National Forest.

2. NORTHERN DRY-MESIC FOREST--This type is moister, shadier and more diverse than the last type and is found on somewhat less sandy soil. White pine is the dominant rather than jack pine. Most of the northern pine forests were of this type. Red maple which grows in this sort of forest creates a spectacular color effect in the early autumn.

   a. DOMINANTS--white pine, red maple, red oak, paper birch, sugar maple
   b. GROUNDLAYER--wood anemone, wild sarsaparilla, ground pine (a club moss), partridge berry, bracken fern, American starflower
   c. TYPICAL ANIMAL LIFE--similar to northern dry forest--red squirrel, red-backed mouse, least chipmunk, Canada jay, red-breasted nuthatch, pine warbler
   d. ENDANGERED SPECIES--bald eagles and ospreys occasionally nest in large pines near the lakeshore; also pine martens

e. THREATS--this type is actually beginning to recover to some degree following the logging era. However, there is no chance that the white pine will return to the abundance of pre-settlement times. During that time, white pine forests dominated large areas of Michigan and Indiana shorelines. Some of these forests have been preserved within state parks and other preserves. However, in other areas because of the esthetic appeal, campgrounds, picnic areas and second home developments have been located in these woods, ruining them as natural areas.

f. EXAMPLES--Wisconsin: Toft Point Scientific Area (Door County), Kohler-Andre State Park (Sheboygan County), Fairy Crasm Scientific Area (Ozaukee County); Illinois: No examples; Indiana: Indiana Dunes State Park (small patches); Michigan: Manistee National Forest, Ludington State Park, Hiawatha National Forest.

3. NORTHERN MESIC FOREST--This forest community, called northern hardwoods by the forester, occupies the most fertile soils and supports the greatest variety of trees of any of the northern communities. This type is also considered a "climax" forest by some ecologists. According to processes of plant succession, most other northern types will eventually change into this type. Conifers are present, especially hemlock, which may form a substantial portion of the forest. Other conifers are more scattered--white pine, balsam fir, white cedar and white spruce. Kuchler (1976) in a vegetational map used by the U. S. Forest Service (Ecosystem of the United States), recognizes a northern hardwood fir type along the shores of the Upper Peninsula of Michigan.

a. DOMINANTS--sugar maple, hemlock, beech, yellow birch, basswood

b. GROUNDLAYER--baneberry, rattlesnake fern, downy Solomon's seal, red eldeberry, yellow trout lilly, squirrel corn, Canada violet, and also a great variety of mushrooms, lichens and mosses

c. TYPICAL ANIMAL LIFE--raccoon, red squirrel, eastern chipmunk, porcupine, ovenbird, red-eyed vireo, veery, redstart, rose-breasted grosbeak, pileated woodpecker

d. ENDANGERED SPECIES--an extinct species, the passenger pigeon, formerly nested in this type of forest. Bald eagles still occasionally nest in large white pines or hemlocks.

e. THREATS--This forest type was once characterized by scattered large white pines, three to six feet in diameter, and fairly evenly spaced throughout the forest. During the pine logging era these northern hardwood stands were largely picked clean of their pines so mesic forests with their original pines are now extremely rare. In many areas, because of their fertile soil, these forests were cleared for crops and pasture land. Those forests that survived are generally managed more carefully than in the past and also produce considerable quantities of maple sugar. Forests along lakeshores are today being invaded by second home development. Beech trees in parks and along nature trails often suffer considerable damage from initial carvers.

f. EXAMPLES--Wisconsin: Peninsula State Park, Newport State Park, Rock Island State Park, Toft Point (all in Door County), Point Beach State Forest; Illinois: no example; Indiana: no example; Michigan: Hoffmaster State Park, Muskegon State Park, Manistee National Forest, Orchard Beach State Park (near Manistee), Wilderness State Park (Emmet County)

4. NORTHERN WET FOREST--These are the spruce-tamerack-sphagnum bogs that have always fascinated ecologists. (The more open bogs will be considered under a separate category.) To one living at the southern end of Lake Michigan, the northern bogs are exotic places for they contain unusual shrubs, orchids and insectivorous plants.

a. DOMINANTS--black spruce, tamarack, white cedar, balsam fir

b. GROUNDLAYER--Laborador tea, Canada blueberry, mountain holly, bog false Solomon's seal, smooth white violet

c. TYPICAL ANIMAL LIFE--black bear, red squirrel, Nashville warbler, parula warbler, olive-sided flycatcher

d. ENDANGERED SPECIES--none presently limited to this type, although the woodland caribou formerly inhabited this type of community

e. THREATS--The southern bogs are endangered by drainage for agriculture. Some of the northern bog forests have been damaged by logging techniques. Other areas are damaged by a lowered water table due to highway construction. Bogs more accessible to the public may have their unique plants dug out for backyards and terrariums.

f. EXAMPLES--Wisconsin: Cedarburg Bog Scientific Area (Ozaukee County), Ridges Sanctuary and Mud Lake Scientific Area (Door County); Illinois: Volo Bog State Nature Preserve (Lake County)-none near Lake Michigan; Indiana: Pinhook Bog, Indiana Dunes National Lakeshore; Michigan: small area at Sarett Nature Center (Benton Harbor), Platte River Tamerack Bog (Benzie County), Whiskey Creek Tract (Charlevoix County)

5. WET MESIC FOREST--Examples of this type are often called cedar swamps for they are often dominated by white cedar. However, this tree may grow along the dry limestone cliffs in Door County, Wisconsin.

   a. DOMINANTS--white cedar, balsam fir, hemlock, yellow birch, black ash

   b. GROUNDLAYER--cinnamon fern, crested fern, showy lady's slipper, goldthread, small enchanter's nightshade, Michigan holly, Canada yew, dwarf raspberry

   c. TYPICAL ANIMAL LIFE--white-tailed deer (important wintering habitat), snowshoe hare, bobcat, long-eared owl, winter wren, Canada warbler

   d. ENDANGERED SPECIES--fisher, bobcat

   e. THREATS--Because of the dense coniferous growth, this forest community is very valuable as a winter habitat for wildlife. Animals such as deer which must rest to conserve energy during periods of deep snow and cold, are now being harassed by increasing use of snowmobiles. Bobcats especially are suffering from this problem. Among plants the showy lady's slipper is becoming increasingly rare because of picking and diggings for gardens. Since these orchids have very specific requirements, they may soon die after being planted in gardens.

   f. EXAMPLES--Wisconsin: Peninsula State Park, Newport State Park, Toft Point, Ridges Sanctuary, Mud Lake (all in Door County), Point Beach State Forest (Manitowoc County), Cedarburg Bog Scientific Area (Ozaukee County); Illinois: No examples near Lake Michigan; Indiana: Cowles Bog, Indiana Dunes National Lakeshore; Michigan: Grand Mere Bog (Stevensville), Allegan State Game Area, Manistee National Forest, South Manitou Island, Wilderness State Park (Emmet County), Ryerse Lake Bog (Mackinac County)

6. BOREAL FOREST--This is a very limited community on the Lake Michigan shoreline and is the timber type most closely related to the upland forests of northern Canada than the white and red pine forests which the average tourist associates with the "North Woods". Boreal forests are much more prevalent along the Lake Superior shoreline than along Lake Michigan.

   a. DOMINANTS--balsam fir, white pine, white cedar, paper birch, white spruce, mountain ash

   b. GROUNDLAYER--red baneberry, bunchberry, large-leaved aster, twinflower, stiff club moss, staghorn club moss, Canada Mayflower, Sharp-lobed hepatica, nodding trillium

   c. TYPICAL ANIMAL LIFE--spruce grouse, yellow-rumped warbler, magnolia warbler, white-throated sparrow, red-backed vole, red squirrel

d. ENDANGERED SPECIES--The woodland caribou was formerly a member of this community. The spruce grouse is presently endangered.

e. THREATS--Some areas of this community are already protected but other areas may be threatened by second home development or logging. The more extensive boreal forests of the Lake Superior shoreline are in greater need of protection.

f. EXAMPLES--Wisconsin: Ridges Sanctuary, Toft Point, Newport State Park, Jackson Harbor Preserve (all in Door County); Illinois: none; Indiana: none; Michigan: Wilderness State Park (Emmet County)

B. SOUTHERN TYPES--This includes many of the forests in the southern half of the Lake Michigan area and is generally distinguished by a greater variety of hardwoods, a general lack of conifers and a different groundlayer. However, here is not the place for neat generalizations for there are many northern elements in the forest communities close to the lakeshore because of the climatic modification by that body of water. An example has already been made of the pine groves within the Indiana Dunes. Another example would be the hemlock, white cedar and Canada yew found in the dunes of Berrian County, Michigan. Old records mention nodding trillium, a boreal forest species, growing in an area now occupied by an inner-city neighborhood in Chicago (Swink, 1974). Just north of Milwaukee there are ravines containing white pine, yellow birch and white cedar. Nevertheless, the typical southern forest communities as they would occur within a few miles of the lakeshore are described below.

1. SOUTHERN MESIC FOREST--This is the southern version of the "climax" forest and is often called a "beech-maple" climax forest. Much of this forest was cleared for farming or altered by logging, but enough remnants have survived so their composition is well known. This forest type is largely lacking a shrub layer but has a rich variety of spring wildflowers.

a. DOMINANTS--sugar maple, basswood, beech, red oak, slippery elm

b. GROUNDLAYER--wild leek, blue cohash, spring beauty, annual bedstraw, sharp-lobed hepatica, Virginia waterleaf, Mayapple, bloodroot, great white trillium, downy yellow violet

c. TYPICAL ANIMAL LIFE--mammals are less plentiful in this community; cerulean warbler, red-eyed vireo, Acadian flycatcher, hairy woodpecker, ovenbird, red-bellied woodpecker, pileated woodpecker; red-backed salamander

d. ENDANGERED SPECIES--wood turtles are considered endangered in Wisconsin and Michigan, while the nodding pogonia orchid is a very rare plant.

e. THREATS--a fairly high proportion of these mesic forests have been protected, but both overuse and abuse by the public threatens to degrade them. Digging and picking wildflowers is common, while beech trees are frequently defaced by carvings in their bark. Many fine trees in Warren Woods in Michigan have been damaged by this latter practice.

f. EXAMPLES--Wisconsin: Cedarburg Beech Woods, Renek-Polak Woods (near Racine), Cudahy Woods, Petrifying Spring Park; Illinois: Harms Woods Forest Preserve, River Trail Nature Center; Indiana: Indiana Dunes State Park; Michigan: Warren Woods Nature Preserve, Warren Dunes State Park, Robinson Preserve (all in Berrien County)

2. SOUTHERN DRY FOREST--This may be characterized as an oak forest which is part of the oak-hickory type as shown on many atlas maps (Kuchler, 1966). However, the hickory in this Lake Michigan area is less prevalent than it is further south. The dry forest is characterized by a dense shrub layer, unlike the mesic forest, often found on sandy or gravelly soil.

a. DOMINANTS--black oak, white oak, bur oak, black cherry, red oak

b. GROUNDLAYER--tall agrimony, grey dogwood, hazelnut, large yellow lady's slipper, pale-leaved sunflower, tall blue lettuce, thicket creeper, yellow cinquefoil, wild blackberry, elderberry, false Solomon's seal, starry false Solomon's seal, carrion flower, common gooseberry

c. TYPICAL ANIMAL LIFE--gray squirrel, fox squirrel, southern flying squirrel, cottontail rabbit, woodchuck, raccoon, opposum, red fox, white-tailed deer, wild turkey, scarlet tanager, black-capped chickadee, downey woodpecker, redheaded woodpecker, cardinal, blue jay, northern oreole, towhee

d. ENDANGERED SPECIES--The eastern box turtle is considered threatened in Michigan, while in Indiana it may be suffering from over-collecting for pets and from mortality on roads. Large yellow lady's slipper may be endangered due to picking and digging.

e. THREATS--This type of woods is susceptible to invasion from off-road vehicles (motorcycles and jeeps) because of the sandy or hilly conditions and because such woods are located close to urban areas.

f. EXAMPLES--Wisconsin: none close to Lake Michigan; Illinois: Sand Ridge Nature Center, Wentworth, Jurgenson and Zanders Woods Forest Preserves (in Cook County); Indiana: Indiana Dunes National Lakeshore; Michigan: Warren Dunes State Park, Grand Mere Woods (near Stevensville), Allegan State Game Area

3. SOUTHERN DRY-MESIC--This is a more diverse type of oak forest than the last community since it is a more fertile environment.

a. DOMINANTS--northern red oak, white oak, basswood, sugar maple, slippery elm

b. GROUNDLAYER--hog peanut, tall anemone, spikenard, Jack-in-the-pulpit, arrow-leaved aster, rattlesnake fern, spring sedge, bittersweet, enchanter's nightshade, honewort, wild yam, shining bedstraw, wild geranium, white avens, bottlebrush grass, yellow honeysuckle, hairy sweet cicely, lopseed, white lettuce, clustered-black snakeroot, upright carrion flower, elm-leaved goldenrod, early meadow rue, bellwort, summer grape, prickly ash

c. TYPICAL ANIMAL LIFE--veery, wood thrush, least flycatcher, redstart, blue-gray nuthatch, yellow-throated vireo, ruby-throated hummingbird

d. ENDANGERED SPECIES--ginseng (It is considered a threatened plant, growing in both dry mesic and mesic woods. It is becoming rare due to collecting for medicinal purposes.)

e. THREATS--Like both the southern dry and mesic woods, this community is often converted to "wooded homesites", being close to urban areas. Large black-walnut trees are becoming scarce as their high lumber value causes them to be selectively cut, often illegally, from protected areas.

f. EXAMPLES--Wisconsin: Sanders Park (Racine County); Illinois: River Trail Nature Center (Cook County), McCormick Ravine (Lake Forest), Thorn Creek Nature Center (Will County); Indiana: Indiana Dunes State Park, Indiana Dunes National Lakeshore; Michigan: Warren Woods State Preserve (Berrien County)

4. SOUTHERN WET FOREST--This is a bottomland forest usually limited to river flood plains, but is sometimes found in swampy lowlands bordering Lake Michigan.

a. DOMINANTS--silver maple, black willow, cottonwood, American elm, swamp white oak

b. GROUNDLAYER--side-flowering aster, false nettle, common wood reed, Virginia wild rye, wood nettle, white grass, moonseed, common satin grass, clearweed, poison ivy, wild goldenglow, mad-dog skullcap, rough hedge nettle, wood sage, riverbank grape, cardinal flower, button bush.

c. TYPICAL ANIMAL LIFE--beaver, wood duck, prothonotary warbler, cardinal, tufted titmouse, red-bellied woodpecker, pileated woodpecker, mosquitoes

d. ENDANGERED SPECIES--otter, massasauga rattlesnake, herons that nest in colonies (all endangered because of human disturbance and pesticides)

e. THREATS--A comparatively sizeable amount of this forest has survived, mostly away from Lake Michigan, but more recently it has been threatened by stream channelization, reservoir construction and clearing for agriculture. Imported Dutch elm disease has killed many elms, altering the structure of this forest type.

f. EXAMPLES--Wisconsin: none in public ownership close to Lake Michigan; Illinois: limited acreage in Cook County Forest Preserves, including Sand Ridge Nature Center; Indiana: Purdue University, Calumet Campus (small patch), Indiana Dunes National Lakeshore (Little Calumet River area); Michigan: Sarett Nature Center (near Benton Harbor)

5. SOUTHERN WET-MESIC--This is a more diverse community which is subject to flooding over shorter periods than the wet forest.

a. DOMINANTS--American elm, silver maple, basswood, white ash, black ash

b. GROUNDLAYER--green dragon, common dodder, wild cucumber, bittersweet nightshade, fringed loose-strife, royal fern, skunk cabbage, sixteen species of sedges

c. TYPICAL ANIMAL LIFE--beaver, wood duck, prothonotary warbler, cardinal, tufted titmouse, red-bellied woodpecker, pileated woodpecker, mosquitoes

d. ENDANGERED SPECIES--otter, massasauga rattlesnake, herons that nest in colonies (all endangered because of human disturbance and pesticides)

e. THREATS--A comparatively sizeable amount of this forest has survived, mostly away from Lake Michigan, but more recently it has been threatened by stream channelization, reservoir construction and clearing for agriculture. Imported Dutch elm disease has killed many elms, altering the structure of this forest type.

f. EXAMPLES--Wisconsin: none public close to the Lake; Illinois: some in Lake and Cook County Forest Preserves; Indiana: Indiana Dunes National Lakeshore; Michigan: Sarett Nature Center (near Benton Harbor)

II. PRAIRIE--The native prairie is the one most threatened by man's activity and the one least understood by the general public. This is because most grassland areas remaining today are not composed of native prairie vegetation, but of Old World weeds and cultivated grasses. Most of the native prairie in the Midwest was plowed up during the latter half of the nineteenth century since it occupied the fertile, black soils of the Corn Belt. Those areas of prairie which occupied land less suitable for cultivation, either sandy, stony, wet or hilly, were heavily grazed by cattle. In the Lake Michigan basin most of the prairie occupied that area now covered by the Chicago and Milwaukee metropolitan area and has largely been converted to building sites.

YET, IN SPITE OF ALL OF THESE PRESSURES, THE PRAIRIE PLANT COMMUNITIES HAVE MANAGED TO SURVIVE IN SMALL PATCHES WHICH HAVE BEEN IN TURN STUDIED BY SCIENTISTS AND IN A FEW CASES, PROTECTED AND EVEN PROPAGATED. THE PRAIRIE COMMUNITY, LIKE THE FORESTS, ARE DIVIDED INTO DIFFERENT COMMUNITIES BASED ON MOISTURE CONTENT. THE PLANTS OF THE PRAIRIE, INSTEAD OF BEING GROUPED INTO DOMINANTS AND GROUNDLAYER, ARE GROUPED INTO GRASSES AND FORBS (THE NON-GRASSES).

A. MESIC PRAIRIE--Once the dominant type of prairie away from Lake Michigan, is now the rarest. Botanically it is the most diverse with grasses and forbs reaching a height of about six feet during the late summer.

    1. GRASSES--big bluestem, Indian grass. northern dropsee[illegible] (shorter than other grasses)
    2. FORBS--cream wild indigo, shooting star, rattlesnake master, dense blazing star, hoary puccoon, white prairie clover, purple prairie clover, prairie phlox, compass plant, prairie dock
    3. TYPICAL ANIMAL LIFE--prairie vole, prairie deer mouse, eastern meadowlark, grasshopper sparrow, fox snake, harvester ant
    4. ENDANGERED SPECIES--the prairie chicken, formerly abundant, is no longer found in the Lake Michigan vicinity. The smooth green snake is endangered.
    5. THREATS--Almost all of the mesic prairie has been converted to agriculture with the exception of small fragments along roadsides, railroad right-of-ways and in some old, rural cemeteries. Other prairie remnants have survived in suburban areas, being owned by generations of land speculators without being farmed. Today these are all threatened--the railroads and roadsides by plowing, mowing and spraying--the cemeteries by mowing and grave-digging--and the suburban vacant land by construction. A few remnants have had their wildflowers dug out by selfish gardeners. Even wildflower photographers can damage prairies by trampling.
    6. EXAMPLES--Wisconsin: none public close to the Lake; Illinois: James Woodworth Prairie (five acres in Glenview, owned by the University of Illinois), Vermont Cemetery (near Plainfield, away from Lake Michigan); Indiana: none near Lake Michigan; Michigan: none close to the Lake

B. DRY PRAIRIE--This type of prairie is usually found on a steep gravelly hill mostly in glacial moraine topography. There may not be any examples surviving close to Lake Michigan. Grasses average less than one meter tall.

    1. GRASSES--little bluestem, side-oats grama
    2. FORBS--pasqueflower, stiff sandwort, woolly milkweed, prairie smoke, grooved yellow flax, fringed puccoon, prairie buttercup, kittentails, silky aster
    3. TYPICAL ANIMAL LIFE--thirteen-lined ground squirrel, badger (formerly), horned lark, several species of small insects and spiders may be limited to this community
    4. ENDANGERED SPECIES--several species of plants are now very rare--woolly milkweed, prairie buttercup and prairie bush clover
    5. THREATS--These areas are frequently converted to gravel pits by mining or are damaged by off-road vehicles that use them for hill-climbing
    6. EXAMPLES--(All outside of the Lake Michigan vicinity.) Wisconsin: several areas in the south unit of the Kettle Moraine State Forest (Eagle Oak Opening, Waukesha County); Illinois: Shoe Factory Road Hill Prairie (Cook County); Indiana: none close to the Lake; Michigan: none close to the Lake

C. DRY-MESIC PRAIRIE--The moisture levels in this prairie are between that of dry prairie and mesic prairie with grass height nearly that of the mesic prairie and species' diversity approach that of mesic prairie. Close to Lake Michigan this type grades into dry-mesic sand prairie. This community on finer textured soil is quite rare in this area.

1. GRASSES--little bluestem, Indian grass, porcupine grass
2. FORBS--lead plant, purple coneflower (away from the Lake), rough blazing star, prairie cinquefoil
3. TYIPCAL ANIMAL LIFE--western meadowlark, monarch butterfly
4. ENDANGERED SPECIES--Although no specific examples can be given, this community is rare enough that a number of plants and possibly some insects may be threatened
5. THREATS--The true dry-mesic prairie has been almost completely destroyed by grazing and cultivation. The few surviving remnants are mostly along railroad right-of-ways and in old rural cemeteries, where they are endangered by herbicides and excessive mowing. The sandier prairies close to the Lake Michigan shore are endangered by housing construction and the destructive use of off-road vehicles, the latter activity even invading protected nature preserves.
6. EXAMPLES--No prairies have been preserved on heavy soil close to Lake Michigan. The following preserved areas are mostly sand prairies--Wisconsin: Chiwaukee Prairie (Kenosha County); Illinois: Illinois Beach State Park (Zion), Gensburg-Markham Prairie (Southern Cook County); Indiana: some in the Indiana Dunes National Lakeshore; Michigan: no examples known.

D. WET PRAIRIE--This type of prairie is flooded for much of the spring season. This has the least plant diversity of the different prairie types and includes some plants and animals considered more typical of "wetlands".

1. GRASSES--blue joint grass, cord grass
2. FORBS--prairie Indian plantain, boneset, blue flag iris, winged loosestrife, water parsnip
3. TYPICAL ANIMAL LIFE--blue-winged teal, sedge wren, chorus frog, prairie crayfish
4. ENDANGERED SPECIES--marsh hawk, short-eared owl, massasauga rattlesnake
5. THREATS--Those few areas that have survived drainage for cultivation are now being cleared for suburban development. Some sizeable prairies in Calumet City, Illinois, have survived until recently when rising land values have made development more economical. These areas in Calumet City have suffered increased flooding as a result of this construction. Preserved wet-prairie remnants have suffered from lowered water tables because of surrounding development. Some nature preserves have been invated by recreational use of all-terrain vehicles.
6. EXAMPLES--Wisconsin: Parts of Chiwaukee Prairie (Kenosha County); Illinois: Illinois Beach State Park (near Zion), Sand Ridge Prairie Nature Preserve (Calumet City); Indiana: Hoosier Prairie (near Griffith); Michigan: no examples known.

E. WET-MESIC PRAIRIE--This type of prairie is flooded for a short period after heavy rains. The grasses are composed of a mixture of mesic and wet prairie species with a much greater plant diversity than just the wet prairie.

1. GRASSES--big bluestem, blue joint grass, switch grass, Indian grass, cord grass
2. FORBS--narrow-leaved loosestrife, sundrops, marsh phlox, balsam ragwort, Culver's root, golden Alexander
3. TYPICAL ANIMAL LIFE--Franklin's ground squirrel, savannah sparrow, smooth green snake
4. ENDANGERED SPECIES--The smooth green snake may be locally threatened due to pesticides

5. THREATS--Similar to wet prairie although this type is probably more vulnerable to trampling by hikers and photographers. The more showy plants may be dug out by thoughtless gardeners, only to die later.
6. EXAMPLES--Wisconsin: Parts of Chiwaukee Prairie (Kenosha County); Illinois: Illinois Beach State Park (near Zion), Gensburg-Markham Prairie (Cook County), Sand Ridge Prairie Nature Preserve (Calumet City); Indiana: Hoosier Prairie (near Griffith).

F. SAND PRAIRIE--This prairie type exists in variations--dry, dry-mesic, wet-mesic, etc., as the typical prairie. However, they will not be described in as great a detail here. Actually, sand prairie is more characteristic of the prairie remnants close to Lake Michigan than the five types previously described, but there is also much intergradation between them on certain types of soils. Also, there is much overlap with the sand savanna which will be discussed later.

A dry sand prairie is very limited and overlaps with foredune and savanna communities. It is noted for its abundance of prickly pear cactus. This plant community can develop on dunes that have once been sandmined such as what has occurred at the Indiana Dunes National Lakeshore.

Dry-mesic sand prairie is more similar to the true prairie with such additional forbs as flax-leaved aster, showy goldenrod and bird's foot violet.

Mesic sand prairie overlaps with shrub prairie and is noted for its lack of heavy soil species such as compass plant and yellow and purple coneflowers.

The wetter types of sand prairies are distinguished by the abundance of several species of ferns--cinnamon fern, royal fern and marsh fern.

1. TYPICAL ANIMAL LIFE--Sand prairies, when large enough, may contain several species of reptiles not found in other areas--bull snake and six-lined racerunner lizard in particular.
2. ENDANGERED SPECIES--Several species of reptiles, including the glass snake lizard, which may be found in sand prairies, can be considered as endangered. Among the plants several species of orchids inhabit the moister types of sand prairies and are also threatened.
3. THREATS--Sand prairies are threatened by urban development and off-road vehicles in particular, while the wetter types, even when in nature preserves, are affected by lower water tables because of surrounding development. More than in other prairies, off-road vehicles are a major threat, even in nature preserves. Unusual and rare plants such as cactus and orchids are dug up by collectors. A more subtle threat is fire suppression which leads to woody plant invasion. All of the midwestern prairies should be burned occasionally during the dormant season to control brush and to convert a build-up of dead thatch into nutritious ash. This is especially true with wet-sandy prairies that have had their water tables lowered by surrounding suburban development, since this change increases the rate of shrub and tree invasion.
4. EXAMPLES--Wisconsin: Chiwaukee Prairie (Kenosha County); Illinois: Illinois Beach State Park (near Zion), Gensburg-Markham Prairie, Sand Ridge Prairie Nature Preserve (both in Cook County); Indiana: Hoosier Prairie (Griffith), areas in the indiana Dunes National Lakeshore; Michigan: Newaygo Prairie in the Manistee National Forest

G. SHRUB PRAIRIE--This is a variation of mesic-sand prairie which contains a mixture of shrubs and prairie plants. A notable feature of this prairie is a groundlayer of mosses. Grasses are the same as on other mesic prairies, but other plants are as follows:

1. SHRUBS--black chokeberry, purple chokeberry, swamp dewberry, early low blueberry, huckleberry, sweet fern
2. FORBS--flat-topped aster, downy sunflower, wild quinine, colic root, rattlesnake master, tall-green milkweed

3. TYPICAL ANIMAL LIFE--towhee, catbird, brown thrasher, indigo bunting, field sparrow, cottontail, red fox

4. ENDANGERED SPECIES--Several endangered orchids are associated with this community.

5. THREATS--Urban development is the biggest danger and may also affect adjacent areas by lowering the water table. This may change the balance between prairie plants and shrubs with the latter being favored. An occasional fire is also needed to maintain this balance. Selfish collectors may dig out the orchids which die after transplanting.

6. EXAMPLES--Wisconsin: no examples known; Illinois: several areas in the Cook County Forest Preserves; Indiana: a few small areas in the Hoosier Prairie (Griffith) and the Indiana Dunes National Lakeshore may fit this category; Michigan: no examples known.

III. SAVANNA

A. SAND SAVANNA--A savanna is a type of community with an open treelayer of less than 80% coverage and a groundlayer dominated by prairie grasses and forbs. The sand savanna is the most prevalent form in the Lake Michigan area, being found on dune and swale areas on either the wind worked dunes or the lower beach ridges. It would be expected that the rolling topography would slow down fires and allow a savanna to develop rather than a sand prairie. There seem to be two types--a dry and dry-mesic type with the former occupying the top of the highest dunes, but they are similar enough to be grouped together here.

1. DOMINANTS--black oak, white oak (in moister areas)
2. GROUNDLAYER--sand reed grass, little bluestem, June grass, porcupine grass, spring sedge, wood betony, bird's foot violet, lupine, prickly pear cactus, hairy puccoon, spiderwort, wild rose, orange milkweed, New Jersey tea, early low blueberry, rough blazing star, showy goldenrod, fern-leaved false foxglove
3. TYPICAL ANIMAL LIFE--fox squirrel, bobwhite quail, eastern bluebird, red-headed woodpecker, hog-nosed snake, blue racer
4. ENDANGERED SPECIES--glass snake lizard (a few may still be found in the sand savannas)
5. THREATS--Much of this community has been destroyed by urban expansion along the Indiana shoreline, especially east and west of Gary. Some sizeable remnants have been recently included within the Indiana Dunes National Lakeshore, but they are presently threatened by the use of off-road vehicles. The dunes closer to Michigan City, Indiana, are more heavily wooded. The savannas in the Indiana Dunes State Park have largely become mostly forested due to fifty years of fire suppression.
6. EXAMPLES--Wisconsin: none close to Lake Michigan; Illinois: Illinois Beach State Park (near Zion), Cook County Forest Preserves (near Calumet City); Indiana: Hoosier Prairie (near Griffith), Indiana Dunes National Lakeshore; Michigan: parts of the Manistee National Forest

B. BUR OAK SAVANNA--This type is similar to the sand savanna community except that it occurs on glacial moraines and has a finer textured soil, rather than sand. The tree layer is dominated by bur oak rather than black oak, and the groundlayer is more typical prairie plants without sand prairie species. This type although formerly widespread, has almost totally disappeared due to grazing in the understory or by succession to forest because of fire exclusion. No preserved examples exist close to Lake Michigan.

IV. AQUATIC COMMUNITIES--These would include all wetland and aquatic open water communities in the Lake Michigan area with the exception of Lake Michigan itself, which will be discussed later.

A. MARSHES--This community is the type most often associated with the term "wetland" in the midwest region. A marsh is defined as an area with surface water present most of the year, dominated by tall grass-like plants. The water here is always fresh, although the soil may range from peat to silty mud to sand. Some very limited brackish marshes have been found in the midwest adjacent to salty springs, but it is not known if there are any close to Lake Michigan. Marshes contain a variety of plant communities which are lumped together in this classification. Generally, the wetter marshes have less plant diversity with the community being affected by fluctuations in water level and muskrat population levels.

1. PLANTS--lake sedge, swamp loosestrife, common reed grass, water knotweed, water heartsease, river bulrush, great bulrush, narrow-leaved and wide-leaved cattails, common arrowhead, water plantain, false aster, mermaid weed, marsh skullcap
2. TYPICAL ANIMAL LIFE--muskrat, sandhill crane, American bittern, least bittern, mallard, black duck, blue-winged teal, shoveler, pied-billed grebe, coot, common gallinule, sora, Virginia rail, king rail, red-winged blackbird, yellow-headed blackbird, long-billed marsh wren, swamp sparrow
3. ENDANGERED SPECIES--yellow rail, American bittern, king rail, Virginia rail are threatened in Illinois; Blanding's turtle may also be threatened in Illinois; swamp rose mallow
4. EXAMPLES--Wisconsin: Seagull Bar Scientific Area (Marinette County), Green Bay Shores Wildlife Area (Ocento County), Mud Lake Wildlife Area, Ridges Sanctuary and Toft Point (all in Door County); Illinois: Illinois Beach State Park (near Zion), Indiana: Indiana Dunes National Lakeshore; Michigan: no public areas known close to Lake Michigan

B. SWAMP--a swamp is different from a marsh in that it is dominated by woody plants and different from a bog in that the soil is a mineral soil rather than an organic one. True forested swamps, being wetter than a southern wet forest, are not found in the Lake Michigan region but are found in the southern United States where they are dominated by bald cypress and water tupelo. Another type of community, the shrub swamp, is fairly common in the Lake Michigan area. The shrub swamp is actually composed of two communities--the shrub swamp in the southern lake basin and the alder thicket in the northern basin.

1. SHRUB SWAMP
    - a. DOMINANTS--red osier dogwood, buttonbush, pussy willow, sandbar willow
    - b. TYPICAL ANIMAL LIFE--yellow warbler, yellow-throat, Traill's flycatcher
    - c. ENDANGERED SPECIES--None, although some of the lady's slipper orchids may be found in just some of the shrub swamps.
    - d. THREATS--The shrub swamp community is actually in a state of expansion due to lack of fire and hay mowing in marshes and sedge meadows (see C). Lowering of the water table due to surrounding development may speed up the change of wet prairies and meadows into shrub swamps. The alder thicket seems to be a fairly stable community in the limited area where it occurs.
    - e. EXAMPLES--Wisconsin: Cedarburg Bog Scientific Area (Ozaukee County); Illinois: Sand Ridge Nature Center (Cook County); Indiana: no good examples known; Michigan: no good examples known

2. ALDER THICKET
    a. DOMINANTS--speckled alder, white spirea
    b. TYPICAL ANIMAL LIFE--alder flycatcher
    c. ENDANGERED SPECIES--None, although some of the lady's slipper orchids may be found in just some of the shrub swamps
    d. THREATS--The shrub swamp community is actually in a state of expansion due to lack of fire and hay mowing in marshes and sedge meadows (see C). Lowering of the water table due to surrounding development may speed up the change of wet prairies and meadows into shrub swamps. The alder thicket seems to be a fairly stable community in the limited area where it occurs.
    e. EXAMPLES--Wisconsin: Ridges Scientific Area and Gardner Wildlife Area (both in Door County); Michigan: Little Brevort Lake (Mackinac County)

C. SEDGE MEADOW--A sedge meadow may have the appearance of a marsh or wet prairie except that the area is dominated by sedges, especially *Carex stricta* (no common name). There are two different types--a northern and a southern one--both playing only a minor part in the Lake Michigan area ecology.

1. NORTHERN SEDGE MEADOW--*Carex stricta*, bluejoint grass, marsh bluegrass, dark green rush, rattlesnake grass, swamp aster, northern bugle weed, bog goldenrod, blue vervain
    a. TYPICAL ANIMAL LIFE--sedge wren, blue-winged teal, sandhill crane (rare)
    b. THREATS--Many fine sedge meadows are being put into cultivation of such specialty crops as lettuce, onions, carrots and mint. Other areas have been heavily grazed or damaged by drainage. Even sedge meadows on publically owned wildlife preserves are turning into shrub swamps because of lack of fire. Fire helps to control shrub invasion.
    c. EXAMPLES--Wisconsin: Toft Point Scientific Area (Door County); Illinois: none; Indiana: none; Michigan: examples unknown
2. SOUTHERN SEDGE MEADOW--*Carex stricta*, blue joint grass, cord grass, fowl manna grass, wild madder, turtlehead, Joe pye weed, marsh vetchling, woundwort
    a. TYPICAL ANIMAL LIFE--sedge wren, blue-winged teal, sandhill crane (rare)
    b. ENDANGERED SPECIES--massasauga rattlesnake
    c. THREATS--Many fine sedge meadows are being put into cultivation of such specialty crops as lettuce, onions, carrots and mint. Other areas have been heavily grazed or damaged by drainage. Even sedge meadows on publically owned wildlife preserves are turning into shrub swamps because of lack of fire. Fire helps to control shrub invasion.
    d. EXAMPLES--Illinois: Sand Ridge Nature Center (Cook County)

D. OPEN BOG--This community generally borders on the wet forest and is the "quaking bog" mat that contains so many unusual plants. It forms a successional stage leading from open water to forest. The bog is distinguished from other wetlands by its continuous groundcover of sphagnum moss and can be divided into two stages--the sedge bog and low shrub bog.

1. SEDGE BOG--This is the floating mat closest to open water.
    a. DOMINANTS--several sedges, sphagnum moss, pitcher plant, sundew, buckbean, pink lady's slipper, rose pogonia, grass pink orchid, calla lily
2. LOW SHRUB BOG--This is the next stage of succession leading to a northern wet forest. This stage can be floating or stationary.
    a. DOMINANTS--Sphagnum moss, *Polytricium* moss, leatherleaf, bog rosemary, bog laurel, bog birch, rusty cotton grass, large cranberry

b. TYPICAL ANIMAL LIFE--red-winged blackbird, sedge wren, leopard frog, garter snake, ring-necked duck

c. ENDANGERED SPECIES--The pitcher plants and orchids are threatened locally due to digging by plant collectors

d. THREATS--Digging of bog plants can reach serious proportions; one small bog in a state nature preserve was completely stripped of its pitcher plants because the wrong person knew they were there. The more southern bogs have been drained or filled in while many of the more northerly bogs away from the Lake have been converted into commercial cranberry bogs which destroy the original plant community. Lakeshore bogs have been destroyed for recreational home development also.

e. EXAMPLES--Wisconsin: Ridges Sanctuary and Toft Point (both in Door County), Cedarburg Bog (Ozaukee County); Illinois: Volo Bog (Lake County--not near Lake Michigan); Indiana: Pinhook Bog (LaPorte County--not near Lake Michigan); Michigan: small bog in Muskegon State Park, Ryerse Lake Bog (Mackinac County)

E. PANNE--This is an unusual and limited wetland community which is formed in sand dunes close to the lakeshore. Where blowouts have been formed in the dunes, the wind may continue to excavate the blowout below the water table. A small pond forms which may support a very distinctive plant community. This is due to the leaching of calcareous minerals from the surrounding dunes. This community is similar to what further inland is called a fen.

1. DOMINANTS--bog arrow grass, bluejoint grass, twig rush, lakeshore rush, shrubby cinquefoil, Kalm's St. John's wort, horned bladderwort, Kalm's lobilia, fringed gentian, nodding ladies' tresses orchid, rose gentian, purple gerardia.
2. TYPICAL ANIMAL LIFE--killdeer, Fowler's toad
3. ENDANGERED SPECIES--This community is so limited and under so many pressures that many of its plants can be considered threatened.
4. THREATS--This limited natural community, whose value has only recently been recognized, is subject to a great deal of recreational and developmental pressure. Some of the best pannes on the Lake Michigan shoreline are in heavily used portions of the Indiana Dunes National Lakeshore with one being right next to the bathhouse. The public use will have to be monitored closely to avoid damage. The largest panne known, located at the east end of Gary, Indiana, might be threatened by federal boat harbor construction.
5. EXAMPLES--Wisconsin: Ridges Sanctuary, Jackson Harbor Scientific Area; Illinois: Illinois Beach State Park; Indiana: Indiana Dunes National Lakeshore; Michigan: Warren Dunes State Park

V. PRIMARY SUCCESSION AREAS

A. BEACH AND DUNE COMMUNITIES--These are probably the ecological communities most associated with Lake Michigan in the minds of naturalists. Dr. Henry Cowles did pioneering work on plant succession in the dunes at the southern end of the Lake which will be discussed in greater detail further on. Two different communities are considered here--beach and foredune.

1. BEACH--Only sparse vegetation exists here, composed largely of highly specialized annuals, scattered grasses and some weedy plants which are common in disturbed soils. This community covers the level area up to the slope of the first dune.

   a. PLANTS--sea rocket, bugseed, seaside spurge, Russian thistle, cocklebur, silverweed, marram grass, beach pea

b. TYPICAL ANIMAL LIFE--various shorebirds use this area during migration; beach tiger beetle, beach ground beetle

c. ENDANGERED SPECIES--Bald eagles once fed on dead fish along Lake Michigan beaches, piping plover once nested in this area but is almost extinct now.

2. FOREDUNE--This community occurs on the low relling dunes adjacent to the level beach. This stage is called "upper beach" in Cowles' succession system. Grasses and shrubs are beginning to dominate this stage. There is some overlap with the sand prairie.

   a. PLANTS--little bluestem, sand reed grass, Canada wild common juniper, trailing juniper (Illinois and Southern Wisconsin), beach wormwood, sand cherry, dune goldenrod, bearberry, wafer ash

   b. TYPICAL ANIMAL LIFE--Thirteen-lined racerunner, lizard, maritime locust, digger wasp, white tiger beetle

   c. ENDANGERED SPECIES--no endangered animals limited to this zone, however, several plants may be considered endangered such as the Dune thistle in Wisconsin

   d. THREATS--Many of the dunes and natural beaches in Illinois and Indiana have been lost to urbanization. Even in those areas that have been protected in parks, heavy recreational use and development (parking areas, bathhouses, etc.) may obliterate much of the natural community. The beach community with its specialized annual plants is most vulnerable to destruction by human traffic--both foot and vehicular. Such use also wears numerous paths through the foredunes, which also become sprinkled with unsightly litter. This type of damage, even in a limited amount, has caused the piping plover to disappear from several state parks around the Lake where it once nested. One state park--Illinois Beach--has part of its nature preserve closed to visitors except by permit because of misuse.

   e. EXAMPLES--Wisconsin: Seagull Bar Scientific Area, Jackson Harbor Preserve, Point Beach State Forest, Kohler-Andrae State Park; Illinois: Illinois Beach State Park; Indiana: Indiana Dunes National Lakeshore and State Park; Michigan: Warren Dunes State Park (Berrien County), Hoffmaster and Muskegon State Parks (Muckegon County), Ludington State Park, Manistee National Forest, Sleeping Bear Dunes National Lakeshore

B. LIMESTONE CLIFFS--This community is limited to the northwest shoreline area of Lake Michigan--the Door Peninsula of Wisconsin and the Garden Peninsula of Michigan. Certain specialized plants are largely limited to cliffs. The majority of the plants adapted for growing on the limestone cliffs are ferns.

1. PLANTS--slender rock brake (fern), purple cliff brake (fern), harebell, columbine, maidenhair spleenwort, cliff fern, bulblet bladder fern, fragile fern, polypody (fern)
2. TYIPCAL ANIMAL LIFE--cliff swallow
3. ENDANGERED SPECIES--This community is so limited that several of the plants which characterize it can be said to be endangered or threatened.
4. THREATS--These cliff communities are threatened by quarrying, logging, fires, home construction. The cliffs in parks are often threatened by recreational overuse. Digging of ferns may also take place.
5. EXAMPLES--Wisconsin: Peninsula State Park, Rock Island State Park, Cave Point, Death's Door County Park (all in Door County); Michigan: Garden Peninsula (specific areas unknown)

BESIDES THE LIMESTONE CLIFF COMMUNITIES, DOOR COUNTY IS NOTED AMONG NATURALISTS FOR A SERIES OF PARALLEL, OLD SAND DUNE RIDGES FORMED OVER THE DOLOMITE BEDROCK. THESE RIDGES CONTAIN A RICH AND COLORFUL VARIETY OF WILDFLOWERS IN ASSOCIATION WITH A SMALL AREA OF BOREAL FOREST FAR REMOVED FROM ITS MAIN RANGE AROUND LAKE SUPERIOR. THE FLORAL DISPLAY IS ESPECIALLY ATTRACTIVE IN LATE MAY TO EARLY JUNE. QUANTITIES OF LAKE IRIS, BIRD'S EYE PRIMROSE, GAY WINGS, YELLOW LADY'S SLIPPER AND INDIAN PAINTBRUSH MAY BE SEEN. THIS COMMUNITY IS WELL PORTECTED AND INTERPRETED AT THE RIDGES SANCTUARY IN BAILEY'S HARBOR, WISCONSIN.

THE SOUTHERN SHORE OF THE LAKE HAS BEEN KNOWN AMONG ECOLOGISTS AS THE LOCATION FOR FIELD STUDIES IN PLANT AND ANIMAL SUCCESSION. AS THE GALAPAGOS ISLANDS BECAME A WORKSHOP FOR EARLY EVOLUTIONARY THEORY, SO THE DUNES OF THE LAKE MICHIGAN SHORELINE PROVIDED THE BASIS FOR EARLY ECOLOGICAL STUDY. MUCH OF THE PLANT ECOLOGY STUDIES WERE MADE BY DR. HENRY COWLES IN 1899 WHILE THE ANIMAL ECOLOGY STUDIES WERE DONE A DECADE LATER BY VICTOR SHELFORD. SO MUCH WAS THE SCIENTIFIC COMMUNITY STIMULATED BY THIS FIELD WORD THAT AN INTERNATIONAL CONVENTION MEETING IN CHICAGO IN 1911 (THE INTERNATIONAL CONGRESS OF GEOGRAPHERS) PROCLAIMED THE INDIANA DUNES TO BE ONE OF THE FOUR NATURAL WONDERS OF THE UNITED STATES ON A PAR WITH YELLOWSTONE, YOSEMITE AND THE GRAND CANYON. ALTHOUGH THE DUNES SHORELINE HAS BEEN PARTIALLY OBLITERATED BY DEVELOPMENT SINCE THAT TIME, ENOUGH REMAINS FOR UNIVERSITY CLASSES AND OTHER GROUPS TO CONTINUE USING THIS AREA FOR THEIR FIELD WORK.

DR. HENRY COWLES, A PROFESSOR AT THE UNIVERSITY OF CHICAGO, WROTE A PAPER IN 1899 THAT DESCRIBED THE STAGES OF PLANT SUCCESSION AS A SERIES OF PLANT COMMUNITIES PARALLELING THE LAKESHORE AND EXTENDING BACK IN CONCENTRIC ZONES TO A CLIMAX FOREST, A VARYING DISTANCE INLAND. VICTOR SHELFORD SOON AFTERWARD ADDED ANIMAL INDICATORS TO EACH COMMUNITY. THE COMMUNITIES ARE GROUPED AS FOLLOWS:

I. PLANT SUCCESSION

A. LOWER BEACH--washed by summer storms
   1. PLANTS--none
   2. TYPICAL ANIMAL LIFE--beach tiger beetle, beach ground beetle, flesh flies (on dead fish), sandpipers

B. MIDDLE BEACH--washed only by severe winter storms; dry in summer; upper limits marked by driftwood and debris; scattered annual plants are present
   1. PLANTS--sea rocket, bugseed, cocklebur
   2. TYPICAL ANIMAL LIFE--white tiger beetle, burning spider, termite (on driftwood), piping plover (nests)

C. UPPER BEACH--where the foredunes are formed; pioneer grasses are dominant with biennial and perennial herbs appearing
   1. PLANTS--marram grass, little bluestem, Canada wild rye, dunes goldenrod, beach wormwood
   2. TYPICAL ANIMAL LIFE--white tiger beetle, maritime locust

D. SHRUB ZONE--may directly invade the grasses but become more common in later tree stages
   1. PLANTS--sand cherry, choke cherry, red osier dogwood, frost grape vine, common juniper
   2. TYPICAL ANIMAL LIFE--syphid flies, robber flies, aphids, eastern kingbird

E. COTTONWOOD ZONE--This tree is replaced by balsam poplar further north; soil is developing from dead leaves.
   1. PLANTS--cottonwood plus shrubs of the shrub zone (I. D.)
   2. TYIPCAL ANIMAL LIFE--digger wasp, crab spider, osprey (formerly), tree swallow

F. PINE ZONE--The pines serve to shade out the cottonwoods and add their needles to the soil
   1. PLANTS--jack pine, white pine
   2. TYPICAL ANIMAL LIFE--bronze tiger beetle, six-lined racerunner lizard, blue racer (snake)

G. BLACK OAK ASSOCIATION--This tree may form a pure stand that will persist for a long time. Open sand is by this stage relatively infrequent.
   1. PLANTS--black oak, many flowering perennials
   2. TYPICAL ANIMAL LIFE--ant lion, solitary wasp, hognosed snake

H. OAK-HICTORY FOREST--Two associations are described by Shelford in this forest
   1. BLACK OAK-WHITE OAK--This is a denser forest than the black oak stage but is less diverse than the second stage.
      a. TYPICAL ANIMAL LIFE--oak-plant bug, oak-gall insect, Polygyra snail, earthworms, ground beetle, root borer, woodchuck
   2. WHITE OAK-RED OAK-HICKORY--This is the climas forest in the drier areas.
      a. TYPICAL ANIMAL LIFE--green-tiger beetle, oak-tree pruner (beetle), ruffed grouse, red fox

I. BEECH-MAPLE FOREST--This is the final stage in the southern Lake Michigan region.
   1. TYIPCAL ANIMAL LIFE--wood frog, red-backed salamander, various land snails, millipedes

The above outlines the process of plant succession as it has been described by the early ecologists and is still taught in many college classes. Most of these stages represent different communities described earlier under the more recent classification system. The beech-maple forest is called the southern mesic forest; the white oak-red oak-hickory is called the southern dry-mesic forest and so on. This neat system of succession is, however, outdated in more ways than one. It is so oversimplified that it may be considered an actual fallacy since it implies that at any point along the shoreline the stages will be the same. Now it is recognized that there is much variation even within the short distance of shoreline within Indiana. Had this been recognized earlier, perhaps there would have been more of the dunes area preserved when land was still available.

In addition to the succession as described for terrestrial sand dune communities, Shelford also studied aquatic succession in a series of long, narrow, parallel ponds between ancient beach ridges. These were located within the northwest side of Gary, Indiana, and extended into what is now part of East Chicago and Hammond. Many of

THEM HAVE BEEN DESTROYED BY URBANIZATION, BUT THERE WERE AT ONE TIME NINETY-FIVE SEPARATE, PARALLEL, LINEAR PONDS WITH THE MOST RECENTLY FORMED PONDS CLOSEST TO LAKE MICHIGAN, AND THE OLDEST ONES SEVERAL MILES INLAND AND SOUTH OF THE GRAND CALUMET RIVER. THE SUCCESSION THAT WAS DESCRIBED FOR THAT AREA CAN BE SUMMARIZED AS FOLLOWS:

II. AQUATIC SUCCESSION

A. BARE BOTTOM STAGE--This was characteristic of the ponds closest to the lake and was inhabited by certain aquatic animals, requiring opening sand for their reproductive and feeding habits.
  1. PLANTS--scattered stonewort (Chara) or no plants
  2. TYIPCAL ANIMAL LIFE--large-mouth bass, bluegill, pumpkinseed sunfish, bullhead, caddis fly larvae, freshwater mussel

B. SUBMERGED VEGETATION--Dense stands of stonewort cover the bottoms of ponts a little further inland forming humus and the beginning of a mud bottom.
  1. PLANTS--much stonewort, scattered bulrushes along the shore
  2. TYPICAL ANIMAL LIFE--In the sparse growth: musk turtle, burrowing dragonfly nymph, a few mussels; In the denser growth: mud minnow, golden shiner, clubsucker, bullhead, grass pike, tadpole catfish, warm-mouth bass

C. EMERGENT AND FLOATING VEGETATION--This is the last major stage in succession and contains a variety of submerged, floating and emergent plants supported by the thick layer of humus covering the bottom. The animals of this stage are adapted for climbing on the stems of the plants.
  1. PLANTS--white water lily, yellow pond lily, pondweeds, water milfoil, hornwort, cattail, bulrush
  2. TYPICAL ANIMAL LIFE--common pond snail, creeping dragonfly, nymph, predacious diving beetle, soldier fly larvae, newt, black bullhead, mud minnow

ANY PONDS BEYOND THIS STAGE WOULD BE MOSTLY MARSH OR SHRUB SWAMP, WHICH WERE DESCRIBED EARLIER IN THE CHAPTER.

THERE IS A GREAT NEED FOR THE FEW UNPOLLUTED PONDS TO BE PRESERVED ALONG WITH THEIR INTERVENING DUNES WHICH ARE COVERED WITH A UNIQUE QUALITY PRAIRIE AND SAND SAVANNA. PRESENTLY THE FEW FRAGMENTS OF THIS TOPOGRAPHY ARE IN A SECTION OF GARY SURROUNDED BY INDUSTRIAL DEVELOPMENT, RAILROADS AND GARBAGE DUMPS. A PROPOSAL TO INCLUDE SOME OF THIS AREA IN THE INDIANA DUNES NATIONAL LAKESHORE WAS REJECTED SINCE IT WAS TOO FAR FROM THE MAIN SECTION OF THE PARK, AND NOW IT IS THREATENED WITH AIRPORT EXPANSION. OTHER WAYS TO PROTECT THE AREA ARE NOW BEING EXPLORED. THERE ARE OTHER PONDS WHICH ARE PART OF A DIFFERENT DUNE FORMATION IN THE NATIONAL LAKESHORE ON THE EAST SIDE OF GARY THAT ARE BEING STUDIED BY LOCAL ECOLOGISTS.

DESPITE THE INTEREST OF THE NATURALIST IN PRESERVING THE NATIVE SHORE COMMUNITIES, THE GENERAL PUBLIC SEEMS MORE PREOCCUPIED WITH WATER QUALITY. TWO OF THE MOST OBVIOUS INDICATORS OF WATER QUALITY TO THE RECREATIONAL PUBLIC ARE THE SPECIES AND ABUNDANCE OF fish that are caught. Since fish are sensitive to changes in water quality, a discussion of history of the fish community might be in order. Other biological indicators of water quality are covered elsewhere in the course.

Relatively little is known of the early conditions before commercial fish made their arrival around 1840. Much of this land was Indian territory until the 1830's when treaties ceded it to the federal government. Before that time the Indians harvested what fish could be caught with bone hooks, spears, fiber nets and even with their hands. This bounty was traded to the French and English at military outposts.

At the time of the first commercial fisherman the main predatory fish was lake trout. Large populations of lake herring, whitefish and walleye were prevalent. Yellow perch was prevalent in the shallower waters of bays and shorelines. In the deeper water seven species of ciscoes (also called chubs) were present. Lake sturgeon were also quite abundant and made spawning runs into several of the rivers. In fact, several of the other species had river spawning stocks--lake trout, whitefish and lake herring. Even the paddlefish, which is now limited to the Mississippi River drainage (where it is rare), was recorded by the Jesuit Missionaries of Green Bay in about 1700.

Whitefish were the mainstay of the early fishery since they were easily taken in shore seines. Their taste was also better than lake trout when salted (often the only means of preservation available). Stream run populations were still available, making them easy to catch as it had been for the Indians. However, settlement along the river valleys soon obliterated these runs by pollution, siltation from logging, drainage of marsh spawning areas and overfishing.

After the mid-nineteenth century, the commercial fishery shifted to the deeper parts of the lake. This was in response to the depletion of the inshore fishery along with the development of factory-made gill nets. The gill nets in turn could be made larger because of the invention of factory-made net haulers. Thus there developed a period of heavy fishery exploitation which paralleled the intensive logging of the pine forests on shoreline areas. This logging served to eliminate stream spawning areas of trout by removing the shade which kept the water temperature low enough for trout reproduction. The population of Atlantic salmon was eliminated from Lake Ontario during the nineteenth century

PARTIALLY BECAUSE OF THIS TREE REMOVAL.

IN THE 1860'S, LAKE ONTARIO WAS THE SCENE FOR ANOTHER THREAT TO THE NATIVE FISH POPULATION. DURING THIS DECADE THE SEA LAMPREY INVADED FROM THE ATLANTIC OCEAN AND ESTABLISHED A POPULATION IN LAKE ONTARIO WHICH WOULD EVENTUALLY SPREAD TO THE OTHER LAKES BY WAY OF THE WELLAND SHIP CANAL. THESE PARASITIC LAMPREY INVADED LAKE MICHIGAN IN THE 1930'S AND BY 1950 REDUCED THE LAKE TROUT POPULATION BY 95%. THE BURBOT, A PREDATORY FISH RELATED TO THE COD, WAS ALSO DECIMATED BY THE LAMPREY. WITH THE DISAPPEARANCE OF THE LARGE CARNIVOROUS FISH ANOTHER SALTWATER INVADER, THE ALEWIFE, WAS ABLE TO BUILD UP ENORMOUS POPULATIONS. ALEWIVES OUT-COMPETED NATIVE FISH FOR THEIR FOOD, COMPRISED MOSTLY OF ZOOPLANKTON. THEY ALSO ATE LARGE QUANTITIES OF SMALL FORAGE FISHES SUCH AS EMERALD SHINERS AND THE YOUNG OF OTHER SPECIES--LAKE HERRING, CISCO, PERCH, WALLEYE, AND SMALL-MOUTH BASS. BY OUT-COMPETING NATIVE SPECIES FOR FOOD AND LIVING SPACE, THEY EVENTUALLY REPLACED THEM, FORMING 80% OF THE FISH BIOMASS.

OTHER INVADERS HAD LESS OF AN IMPACT. THE CARP WERE BROUGHT FROM GERMANY IN THE 1890'S TO PROVIDE A FOOD FISH. THEY BECAME A SERIOUS PROBLEM IN MANY SHALLOW INLAND LAKES, UPROOTING SUBMERGED PLANTS AND MUDDYING THE WATERS, CHANGING THE HABITAT FOR FISH AND WATERFOWL ALIKE. HOWEVER, IN THE MORE OLIGOTROPHIC WATERS OF LAKE MICHIGAN THEY WERE LESS OF A PROBLEM. SMELT, THE FIRST MARINE FISH TO BE ESTABLISHED IN THE GREAT LAKES, WERE PLANTED IN 1912 IN CRYSTAL LAKE, MICHIGAN, WHICH DRAINS INTO LAKE MICHIGAN. SMELT SPREAD TO ALL THE GREAT LAKES, REACHING COMMERCIAL IMPORTANCE IN THE EARLY 1940'S, EVENTUALLY BECOMING SECOND ONLY TO THE LAKE HERRING IN WEIGHT HARVESTED. A MAJOR RECREATIONAL FISHERY DEVELOPED AS WELL. HOWEVER, THE SMELT, UNLIKE THE ALEWIFE, DID NOT COMPETE ENOUGH TO REPLACE THE NATIVE SPECIES.

THE RESULT OF ALIEN INVADERS AND HEAVY FISHING PRESSURE HAS BEEN TO ELIMINATE SOME OF THE NATIVE SPECIES. THE CISCO OR CHUBS HAVE BEEN ESPECIALLY AFFECTED. THE LARGEST AND MOST COMMERCIALLY VALUABLE SPECIES, THE BLACKFIN CISCO, HAVE BEEN ENTIRELY ELIMINATED ALONG WITH THE DEEPWATER CISCO. THESE SPECIES WERE ALREADY BECOMING DEPLETED DUE TO HEAVY COMMERCIAL FISHING. THREE OTHER SPECIES--THE LONGJAW CISCO, SHORTJAW CISCO AND SHORTNOSE CISCO ARE CLOSE TO EXTINCTION, WHILE THE KIYI IS CONSIDERED THREATENED. ONLY THE BLOATER IS IN COMMERCIALLY USEFUL NUMBERS WHICH IS IRONIC SINCE THIS ONE IS THE LEAST VALUABLE TO THE COMMERCIAL FISHERMAN. IT IS POSSIBLE THAT THE BLOATER HAS HYBRIDIZED WITH THE OTHER CISCO SPECIES, LEAVING THE PUREBRED CISCOES TO DIE OUT. THE BLOATER IS ALSO DECLINING DUE TO OVERFISHING.

THE LAKE STURGEON HAVE ALSO DECLINED CONSIDERABLY AND NOW SHOW ONLY SIZEABLE RUNS ON THE MENOMINEE RIVER WHICH SEPARATES WISCONSIN FROM THE UPPER PENINSULA OF MICHIGAN.

A CONSIDERABLE EFFORT WAS CONDUCTED TO CONTROL LAMPREYS BEGINNING IN THE EARLY 1950'S WITH MECHANICAL AND ELECTRICAL BARRIERS PLACED ACROSS THEIR SPAWNING STREAMS. THIS PROCEDURE WAS REPLACED WITH THE USE OF THE CHEMICAL "TMF" WHICH POISONS LAMPREY YOUNG WITHOUT AFFECTING OTHER AQUATIC LIFE. AS A RESULT OF THIS TREATMENT, THE LAMPREY HAVE BEEN REDUCED TO A MUCH LOWER LEVEL SO THAT THE LAKE TROUT AND OTHER PREDATORY SPECIES COULD BE RESTOCKED.

THE COHO SALMON WAS INTRODUCED IN 1966 AND THE CHINOOK IN 1967 AND STARTED A MAJOR RECREATIONAL FISHING BOOM THE SAME YEAR. HOWEVER, DESPITE THE SPECTACULAR RESULTS, THE SALMON DID NOT ESTABLISH A SELF-REPRODUCING POPULATION AND STILL HAVE TO BE MAINTAINED BY STOCKING. CONSIDERABLE STOCKING OF OTHER SPECIES--LAKE, RAINBOW, BROOK AND BROWN TROUT, IS TAKING PLACE ALSO WITH TWO HYBRIDS--SPLAKE (LAKE TROUT X BROOK TROUT) AND TIGER TROUT (BROWN X BROOK TROUT). A FRESH WATER SPAWNING RUN OF LAKE TROUT ON THE FORD RIVER IN UPPER PENINSULA MICHIGAN HAS BEEN ESTABLISHED. THREE OTHER SPECIES OF SALMON HAVE BEEN INTRODUCED--THE KOKANEE, PINK AND ATLANTIC SALMON. THE "GALLSPANG" VARIETY OF ATLANTIC SALMON FROM LANDLOCKED LAKES IN SWEDEN, HAVE BEEN INTRODUCED SINCE THE NATIVE VARIETY HAVE BEEN UNSUCCESSFUL. THE PINK SALMON IS THE ONLY SPECIES TO ESTABLISH A SELF-REPRODUCING POPULATION.

OTHER FISH SPECIES FORMERLY DECIMATED BY THE LAMPREY HAVE RECOVERED RECENTLY INCLUDING WHITEFISH, BURBOT, WHITE SUCKER, CARP, POSSIBLY PERCH AND IN SOME AREAS, SMELT. HOWEVER, WALLEYE AND CHUBS (CISCOES) ARE DECLINING, THE FORMER FOR UNKNOWN REASONS, THE LATTER BECAUSE OF HEAVY COMMERCIAL FISHING PRESSURE AND COMPETITION WITH THE ALEWIFE. EVEN THE MOST NUMEROUS SPECIES OF CHUB, THE BLOATER, HAS BEEN DECREASING RAPIDLY SINCE 1969. HOPEFULLY, DUE TO CONTINUED STOCKING OF ALEWIFE PREDATORS AND AN INCREASED COMMERCIAL HARVEST OF THIS FISH SPECIES, A MORE HEALTHY BALANCE WILL BE ESTABLISHED.

WITHIN RECENT YEARS MUCH CONCERN HAS BEEN EXPRESSED OVER TOXIC CONTAMINATION BY PCB'S, DDT AND VARIOUS OTHER COMPOUNDS. THE PCB CONTAMINATION IS STILL A SERIOUS PROBLEM, ALTHOUGH THE DDT CONTAMINATION HAS DROPPED CONSIDERABLY SINCE ITS USE WAS LARGELY OUTLAWED IN 1972. THIS DECREASE OF THE LATTER COMPOUND HAS BEEN REFLECTED IN THE INCREASED NESTING SUCCESS OF BALD EAGLES OVER THE LAST TWO SEASONS. THE PCB CONCENTRATIONS MIGHT BE REDUCED ONCE PCB CONTAMINATED DEPOSITS CAN BE FEASIBLY REMOVED FROM HARBORS. GENERALIZED POLLUTION FROM INDUSTRIAL WASTE AND SEWAGE HAS BEEN REDUCED AS WELL, CAUSING FISH TO BEGIN TO RETURN TO AREAS ONCE BADLY CONTAMINATED. AN EXAMPLE IS THE RECENT RETURN OF WALLEYES AND PERCH TO AREAS OF GREEN BAY AND THE FOX RIVER AS PAPER MILLS ALONG THE RIVER MEET DISCHARGE REQUIREMENTS.

SO, GRADUALLY A HIGH QUALITY FISH POPULATION IS RETURNING TO LAKE MICHIGAN. HOWEVER, IT WILL PROBABLY BE IMPOSSIBLE TO DUPLICATE PRE-SETTLEMENT CONDITIONS. THE ALEWIFE IS TOO WELL ESTABLISHED AND THE BLACKFIN AND DEEPWATER CISCO ARE NO DOUBT GONE FOREVER. NEVERTHELESS, THERE IS STILL MUCH ROOM FOR CAUTIOUS OPTIMISM.

OVER THE PAST HALF CENTURY THERE HAVE BEEN EFFORTS BY CITIZENS AND GOVERNMENT AGENCIES TO PRESERVE THE NATURAL AREAS NEAR THE SHORELINE OF LAKE MICHIGAN. FEDERAL, STATE, LOCAL AND PRIVATE AGENCIES HAVE ALL BEEN INVOLVED WITH AN INCREASED AMOUNT OF ACTIVITY IN RECENT YEARS. THIS IS FORTUNATE BECAUSE THE NEED FOR PRESERVATION HAS GREATLY INCREASED DUE TO GROWING POPULATION PRESSURES. THE RECENT BOOM IN RECREATION HAS RESULTED IN SECOND HOME DEVELOPMENT, PRIVATE CAMPGROUNDS, OFF-ROAD VEHICLES; EACH OF THESE IN TURN CREATE ADDITIONAL PRESSURES ON THE LAKE RESOURCE. THIS, ADDED TO THE CONTINUED GROWTH OF MORE "TRADITIONAL" TYPE LAND USE PRESSURES--URBAN SPRAWL, INDUSTRIAL DEVELOPMENT AND HIGHWAY CONSTRUCTION, MAKES PRESERVATION A NECESSITY RATHER THAN A LUXURY.

THE LAND PRESERVATION EFFORT WILL BE DISCUSSED AS IT HAS BEEN ACCOMPLISHED ON DIFFERENT LEVELS.

I. ROLE OF THE FEDERAL GOVERNMENT

A. THE NATIONAL PARK SERVICE--This agency is the one most associated in the public's mind with conservation, yet here in the Lake Michigan Area it is exhibited in a less traditional form--the national lakeshore--is under its direction.

The national lakeshore is a Great Lake's version of a national seashore. These areas are not considered by the National Park Service to be unique enough in terms of scenic or scientific attributes to quality them for recognition as national parks or monuments, respectively. The primary purpose of national lakeshores and seashores has been to serve as natural outdoor recreation areas.

The two national lakeshores along Lake Michigan are Indiana Dunes (about 10,000 acres) at the southern end of the lake and Sleeping Bear Dunes (about 60,000 acres) near the north end of the lake in Michigan. The classification of national lakeshores as recreation areas has led to problems, especially with the Indiana Dunes where Park Service planners have frequently threatened the survival of fragile ecological areas with incompatible recreational facilities. Recently off-road vehicle pressure groups have demanded that a sizeable tract of dunes, containing the best example of sand savanna, be permanently designated for their exclusive use.

Another problem in the Indiana Dunes area is the fact that the lakeshore is bordered by industrial and residential development. Two of the park's natural areas--the Cowles Bog and the Pinhook Bog--have been designated as National Natural History Landmarks. Several tracts in Sleeping Bear Dunes are being considered for designation as Wilderness areas. Both of the national lakeshores are in the process of land acquisition and are devising their master plans. If they can survive the threat of excessive and inappropriate recreational development, they will offer an excellent opportunity to preserve shoreline formations and ecological communities for public use.

B. THE UNITED STATES FOREST SERVICE--Two national forests are located along the Lake Michigan shoreline--Mainstee National Forest and Hiawatha National Forest--both in Michigan.

The National Forests are operated in a different manner than the national parks in that they are being managed for multiple use (recreation, forestry, wildlife, watershed protection, mineral resources and grazing) rather than just environmental protection and recreation. Nevertheless, there is greater control over incompatible land use than under private ownership, and a vast area has been restored from its former cut-over condition. One area along the lake in the Manistee National Forest (the Nordhouse Dunes Area north of Ludington) is being considered for possible designation as a national wilderness area. In other areas in these national forests that are located away from the lakeshore, several tracts of land are being considered for wilderness protection also. In addition, there are smaller areas preserved in the forests as "natural areas"--an 80-acre area of dry prairie in Manistee and a 200-acre tract of northern mesic forest in Hiawatha. The latter forest is noted for its nesting population of sand hill cranes.

C. UNITED STATES FISH AND WILDLIFE SERVICE--Several small islands in the northern part of Lake Michigan have been designated as National Wildlife Refuges under this agency. These include in Wisconsin--Gravel Island National Wildlife Refuge (27 acres) and Green Bay National Wildlife Refuge (2 acres); and in Michigan--the Michigan Island National Wildlife Refuge (134 acres), including one island in Lake Huron. These have also been made into wilderness areas. The islands are nesting grounds for herring and ring-billed gulls, common and caspian terns and other species.

II. THE STATES' ROLES IN LAND PRESERVATION

A. STATE PARKS AND FORESTS--All four of the Lake Michigan states have acquired land along the shoreline for state parks. Illinois and Indiana have only one lakeshore state park apiece because of their limited shorelines. Wisconsin has seven; Michigan has nineteen (including two now within the Sleeping Bear Dunes National Lakeshore). Although these were established for recreation, many have sizeable natural areas within them. Some of the best dune formations have been preserved within the state parks. Wisconsin is also acquiring a new state park--Whitefish Bay--in Door County, which will include the highest dunes in that state. Other state parks within Door County preserve the limestone cliffs discussed earlier in this chapter. State forests which differ from state parks in permitting timber management also contain natural areas. There are eight state forests on the Michigan side and one on the Wisconsin shore of the lake.

B. STATE CONSERVATION AREAS--These are lands devoted to wildlife management which generally include hunting and fishing. They protect some sizeable wetlands along the shores of Green Bay. Within the city of Chicago along the Illinois-Indiana state line, the William F. Powell Conservation Area maintains the western half of Wolf Lake for fishing and picnicing. Very little of this lake's shoreline is in a natural condition, however. Michigan and Indiana have sizeable state wildlife management areas, but they are located away from Lake Michigan.

C. STATE NATURAL AREA PRESERVES--These are the real backbone of natural land preservation within the lakeshore area. These areas are found in all four states and consist of lands within state parks, forests, wildlife areas, as well as tracts managed by other agencies. These preserves are protected from any further development and have recognized ecological value. Illinois with its nature preserve system, established in 1963, and Wisconsin with its scientific areas system, beginning in 1951, are pioneers in this field. Many areas mentioned as examples under the different ecological communities are protected by these systems. Indiana, starting in 1967, has preserved over 1500 acres of the 2100 acre Indiana Dunes State Park as a nature preserve. Michigan, beginning its winderness and natural areas system in 1972, has begun establishing nature preserves along the lakeshore, including Warren Dunes and Warren Woods Nature Study Areas. In addition, Wisconsin and Indiana, using the funds of the Federal Coastal Zone management Act of 1972, have been conducting a formal inventory of quality natural areas, both public and private, protected and otherwise. Illinois has just completed an inventory of the entire state, which included several natural areas along Lake Michigan.

III. ROLES OF COUNTY AND LOCAL GOVERNMENTS--Several county governments, particularly in the urbanized south end of the lake, have established county park and forest preserve systems. While a few of these areas are close to the lake, they do provide protection for many areas of natural land in heavily populated areas where they would otherwise not exist. In rural areas at the upper end of the lake there are large acreages of county forest land, managed on a multiple-use basis, but it is uncertain how much of this is near the lake.

Municipal park systems do provide some land protection in urban areas, although much of this land is closely manicured. The Chicago lakefront parks have become popular areas for the study of migratory birds with two small bird sanctuaries that have been set aside and managed for this purpose. Milwaukee has merged its county and city park systems and has several natural woodlands located in suburban areas.

IV. ROLES OF UNIVERSITIES--Several universities in Michigan and Wisconsin have provided protection for shoreline areas, including some that are also designated as Wisconsin State Scientific Areas.

V. ROLES OF PRIVATE PRESERVATION EFFORTS

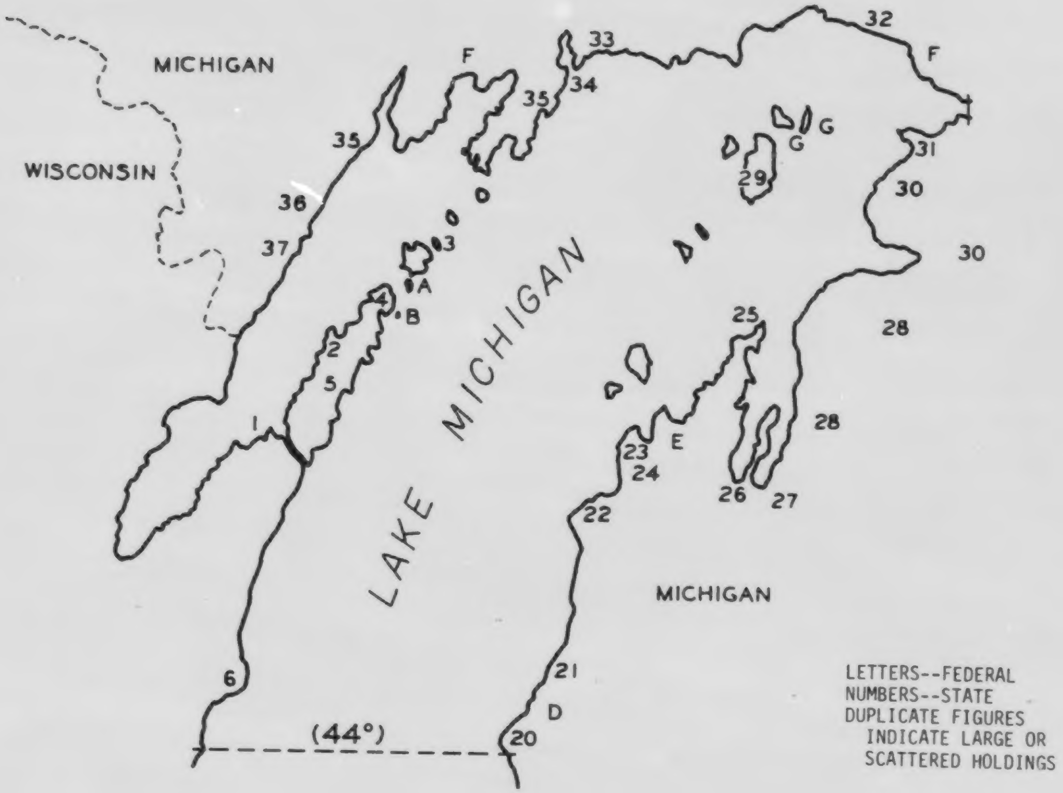
A. NATURE CONSERVANCY--This is the most effective private organization for preserving natural land in the country. Nearly one-and-one-quarter-million acres of land in nearly two-thousand projects have been preserved throughout the United States since 1954. Although many areas have been conveyed to public agencies, about 60% of all areas have been retained by the Conservancy and maintained by volunteer land stewards. Most of those areas acquired by the Conservancy along the lakeshore have been deeded to state and federal agencies, which have been previously mentioned. The Conservancy has the ability to buy lands when they are available and hold them until public agencies can appropriate funds for their transfer.

B. OTHER ORGANIZATIONS--The Ridges Sanctuary Association has acquired on their own several hundred acres of dune ridges on the Door Peninsula near Bailey's Harbor, Wisconsin, before Nature Conservancy had begun their assistance. The Michigan Nature Association owns a number of small preserves, almost all of them away from the lakeshore. The Michigan Audobon Society owns several sanctuaries, including the Sarett Nature Center near Benton Harbor.

WITH SUCH PRESERVATION EFFORTS IN PROGRESS, THERE IS STILL MUCH ROOM FOR INPUT FROM CITIZEN CONSERVATIONISTS. IT IS HOPED THAT THOSE INFORMED BY STUDYING THIS CHAPTER WILL BE INTERESTED IN PRESERVING OUR NATURAL HERITAGE AND WILL SUPPORT SUCH ORGANIZATIONS AS THE NATURE CONSERVANCY, THE LAKE MICHIGAN FEDERATION, THE SAVE THE DUNES COUNCIL (INDIANA), THE CHICAGO OPEN LANDS PROJECT AND VARIOUS OTHER LOCAL, STATE AND FEDERAL ORGANIZATIONS. THIS IS THE ONLY EFFECTIVE WAY TO PRESERVE THE UNIQUE FEATURES OF LAKE MICHIGAN AND ITS SURROUNDINGS.

* * *

STATE AND FEDERAL HOLDINGS
MENTIONED IN THE CHAPTER


MICHIGAN
WISCONSIN
F
33
32
F
35
34
35
G
G
31
30
36
29
30
37
3
A
B
4
LAKE MICHIGAN
25
28
2
5
1
28
23
E
24
26
27
22
MICHIGAN
6
21
D
20
(44°)

LETTERS--FEDERAL
NUMBERS--STATE
DUPLICATE FIGURES
INDICATE LARGE OR
SCATTERED HOLDINGS

KEY TO STATE AND FEDERAL HOLDINGS ALONG LAKE MICHIGAN

WISCONSIN

1. POTAWATOMI S. P.
2. PENINSULA S. P.
3. ROCK ISLAND S. P.
4. NEWPORT S. P.
5. WHITEFISH BAY S. P. (being acquired)
6. POINT BEACH S. F.
7. JOHN M. KOHLER S. P.
8. TERRY ANDRAE S. P.
9. HARRINGTON BEACH S. P.

A. GREEN BAY N. W. R.
B. GRAVEL ISLAND N. W. R.

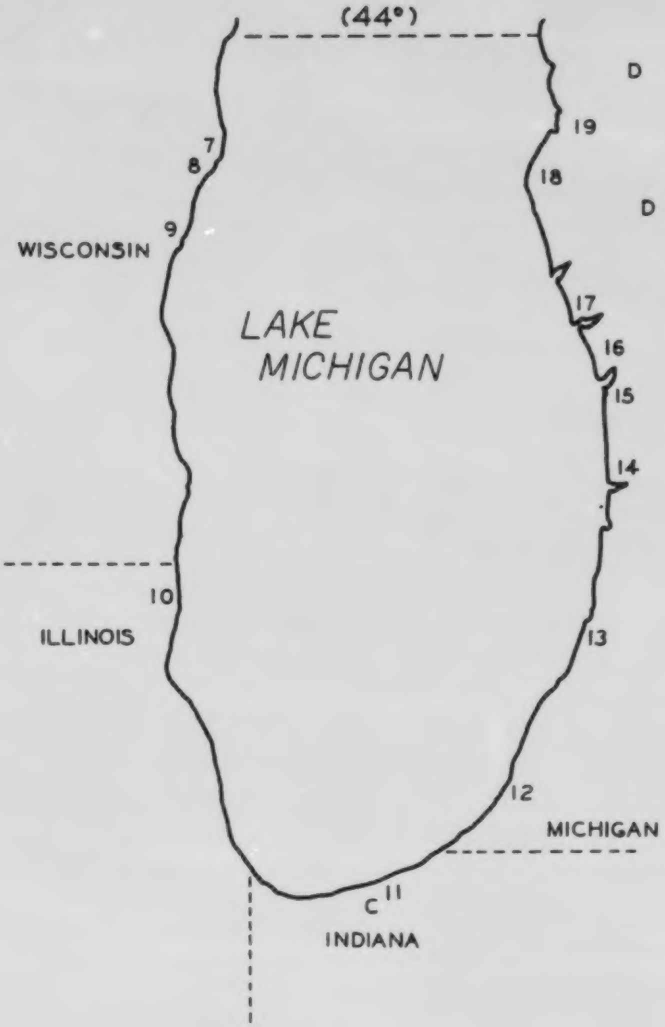
ILLINOIS

10. ILLINOIS BEACH S. P.

INDIANA

11. INDIANA DUNES S. P.

C. INDIANA DUNES N. L.



MICHIGAN

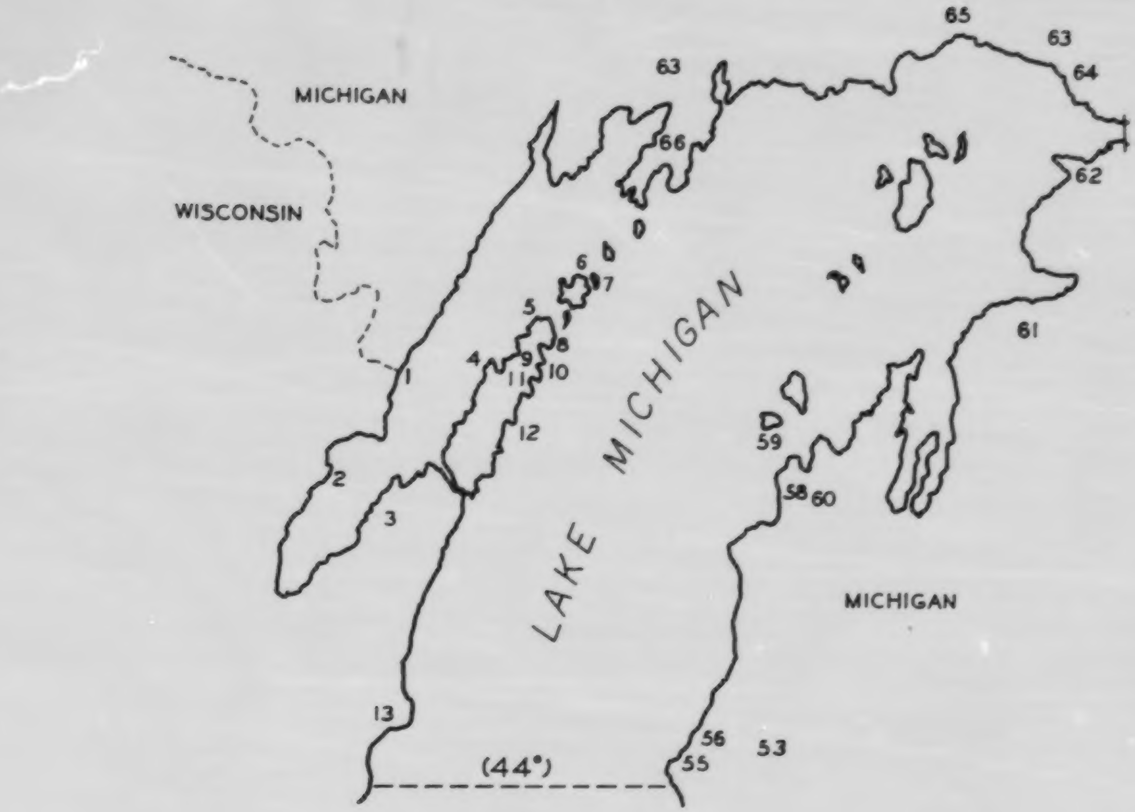
12. WARREN DUNES S. P.
13. VAN BUREN S. P.
14. HOLLAND S. P.
15. GRAND HAVEN S. P.
16. P. J. HOFFMASTER S. P.
17. MUSKEGON S. P.
18. SILVER LAKE S. P.
19. CHARLES MEARS S. P.
20. LUDINGTON S. P.
21. ORCHARD BEACH S. P.
22. BENZIE S. P.
23. D. H. DAY S. P.
24. LEELANAU S. P.
25. TRAVERSE CITY S. P.
26. BETSIE RIVER S. F.
27. FIFE LAKE S. F.
28. JORDAN RIVER S. F.
29. PIGEON RIVER S. F.
30. HARDWOOD S. F.
31. WILDERNESS S. P.
32. MACKINAC S. F.
33. MANISTIQUE RIVER S. F.
34. INDIAN LAKE S. P.
35. BAY DE NOC S. F.
36. MENOMINEE S. F.
37. J. W. WELLS S. P.

D. MANISTEE N. F.
E. SLEEPING BEAR DUNES N. L.
F. HIAWATHA N. F.
G. MICHIGAN ISLANDS N. W. R.

KEY TO ABBREVIATIONS

N. L.--National Lakeshore
N. W. R.--National Wildlife Refuge
S. F.--State Forest
S. P.--State Park (not including historical and fish and game areas.)

EXAMPLES OF NATURAL AREAS MENTIONED IN THE CHAPTER



KEY TO NATURAL AREAS ALONG LAKE MICHIGAN

WISCONSIN

1. SEA GULL BAR--M. DUN
2. GREEN BAY SHORES WILDLIFE AREA--M
3. GARDINER WILDLIFE AREA--AT
4. PENINSULA STATE PARK--NM, NWM, LC
5. DEATH'S DOOR COUNTY PARK--LC
6. JACKSON HARBOR SCIENTIFIC AREA--BF, PAN, DUN
7. ROCK ISLAND STATE PARK--NM
8. NEWPORT STATE PARK--NM, NWM, BF
9. MUD LAKE WILDLIFE AREA--NW, NWM
10. TOFT POINT--NDM, NM, NWM, BF, AT, NS, BOG
11. RIDGES SANCTUARY--NW, NWM, BF, BOG, PAN
12. CAVE POINT--LC
13. POINT BEACH STATE FOREST--NM, DUN
14. KOHLER-ANDRAE STATE PARKS--NDM
15. CEDARBURG BOG--NW, SHSW, BOG
16. CEDARBURG BEECH WOODS--SM
17. FAIRY CHASM SCIENTIFIC AREA--NDM
18. CUDAHY WOODS COUNTY PARK--SM
19. EAGLE OAK OPENING--PD
20. RENEK-POLAK WOODS--SM
21. SANDERS PARK--SDM
22. PETRIFYING SPRINGS PARK--SM
23. CHIWAUKEE PRAIRIE SCIENTIFIC AREA--PDM, PW, PWM, PS

ILLINOIS

24. ILLINOIS BEACH STATE PARK--PDM, PW, PWM, PS, SSAV, PAN
25. VOLO BOG NATURE PRESERVE--NW, BOG
26. McCORMICK RAVINE-SDM

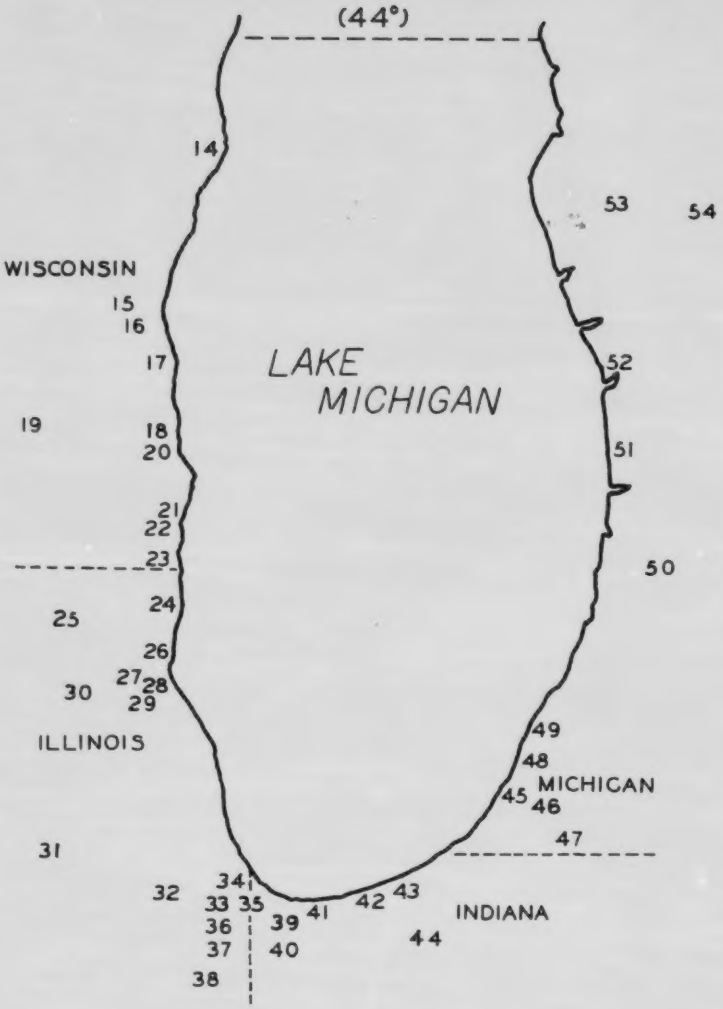
27. RIVER TRAILS NATURE CENTER--SDM, SWM
28. HARMS WOODS FOREST PRESERVE--SM
29. JAMES WOODWORTH PRAIRIE--PM
30. SHOE FACTORY ROAD PRAIRIE NATURE PRESERVE--PD
31. VERMONT CEMETERY--PM
32. GENSBURG-MARKHAM PRAIRIE--PDM, PWM
33. SAND RIDGE NATURE CENTER--SD, SW, SHSW
34. SAND RIDGE PRAIRIE NATURE PRESERVE--PW, PWM, PS, SSAV, SS
35. WENTWORTH WOODS FOREST PRESERVE--SD, SSAV
36. ZANDER'S WOODS FOREST PRESERVE--SD, PSH
37. JURGENSON WOODS FOREST PRESERVE--SD
38. THORN CREEK WOODS NATURE CENTER--SDM

INDIANA

39. PURDUE UNIVERSITY WOODS--SW
40. HOOSIER PRAIRIE NATURE PRESERVE--PW, PWM, PS PSH, SSAV
41. INDIANA DUNES NATIONAL LAKESHORE--ND, SM, SD SDM, SW, SWM, SSAV, PAN, DUN
42. COWLES BOG--NWM
43. INDIANA DUNES STATE PARK--ND, NDM, DUN
44. PINHOOK BOG--NW, BOG

MICHIGAN

45. WARREN DUNES STATE PARK--SM, SD, DUN
46. WARREN WOODS NATURE PRESERVE--SM, SDM, PAN
47. ROBINSON PRESERVE--SM
48. GRAND MERE BOG--NWM, SD
49. SARETT NATURE CENTER--NW, SW, SWM
50. ALLEGAN STATE GAME AREA--NWM, SD
51. HOFFMASTER STATE PARK--NM, DUN
52. MUSKEGON STATE PARK--ND, NM, BOG, DUN
53. MANISTEE NATIONAL FOREST--NDM, NM, SSAV
54. NEWAYGO PRAIRIE--PS
55. LUDINGTON STATE PARK--ND, NDM
56. NORDHOUSE DUNES AREA--ND, DUN
57. ORCHARD BEACH STATE PARK--NM
58. SLEEPING BEAR DUNES NATIONAL LAKESHORE--DUN
59. SOUTH MANITOU ISLAND--NWM
60. PLATTE RIVER TAMARACK BOG--NW
61. WHISKEY CREEK TRACT--NW
62. WILDERNESS STATE PARK--NM, NWM, BF
63. HIAWATHA NATIONAL FOREST--NDM, NM
64. LITTLE BREVORT LAKE--AT
65. RYERSE LAKE BOG--NWM, BOG
66. GARDEN PENINSULA--LC



KEY TO ABBREVIATIONS OF NATURAL AREAS

AT--Alder Thicket
BF--Boreal Forest
BOG--Open Bog
DUN--Lake Dunes
LC--Limestone Cliff
M--Marsh
ND--Northern Dry Forest
NDM--Northern Dry-Mesic Forest
NM--Northern Mesic Forest
NS--Northern Sedge Meadow
NW--Northern Wet Forest
NWM--Northern Wet-Mesic Forest
PAN--Panne
PD--Dry Prairie
PDM--Dry Mesic Prairie
PM--Mesic Prairie
PW--Wet Prairie
PWM--Prairie Wet-Mesic
PS--Sand Prairie
PSH--Shrub Prairie
SD--Southern Dry Forest
SDM--Southern Dry-Mesic Forest
SHSW--Shrub Swamp
SM--Southern Mesic
SS--Southern Sedge Meadow
SSAV--Sand Savanna
SW--Southern Wet Forest
SWM--Southern Wet-Mesic Forest

VISITING NATURAL SITES

When visiting any of the particular sites on the previous lists, please respect their fragility and do not abuse their natural characteristics by collecting or by any other unnecessary disturbance. Areas not within state or federal parks or forests may require prior permission for entry. For information regarding specific sites contact the following agencies:

The Nature Conservancy
Wisconsin Chapter
Div. of Tourism, Room 117
123 W. Washington Avenue
Madison, Wisconsin 53702

The Nature Conservancy
Illinois Chapter
666 North Lake Shore Drive
Suite 1919
Chicago, Illinois 60611

The Nature Conservancy
Indiana Field Office
Rt. 1, Box 155
Nashville, Indiana 47488
(812) 988-7547

The Nature Conservancy
Michigan Field Office
Suite F, 531 N. Clippert St.
Lansing, Michigan 48912

Scientific Areas Preservation Council
Box 450
Madison, Wisconsin 53701

Illinois Nature Preserves Commission
819 North Main Street
Rockford, Illinois 61103

Division of Nature Preserves
In. Dept. of Natural Resources
Rm. 601, State Office Bldg.
Indianapolis, Indiana 46204

State of Michigan
Dept. of Natural Resources
Wilderness and Natural Areas Program
Stevens T. Mason Building
Box 30028
Lansing, Michigan 48909

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MARK RESHKIN

GLOSSARY

BEACH: a shoreline zone of unconsolidated earth materials, usually quartz sand, that extends landward from the shoreline to the place where there is a marked change in material or topographic form (sand dunes or till cliffs around Lake Michigan) or to the line of permanent vegetation.

BEACH NOURISHMENT: the natural deposition of sediments as part of the beach deposit by littoral currents and wave action. To simulate the natural processes in some locations where erosion has been severe, beaches are rebuilt artificially by placing sand on the shore generally from sources behind the beach.

BOTTOM TOPOGRAPHY: the topography developed on top of the sediments below the waters of Lake Michigan.

CLIFF AND SAND DUNE RECESSION: the retreat landward of coastal sand dunes or cliffs (bluffs) as the result of shoreline erosion, primarily wave erosion at the base of the landform and slumping (collapse) of the overlying earth materials. The recession can be measured at either the base of the landform or at the crest, or at both locations.

GLACIAL TILL: unstratified glacial sediments deposited directly by ice and consisting of clay, sand, gravel, and boulders intermingled in any proportion.

HYDRAULIC ACTION: one of the water erosion processes, it is the direct effect of sediment particles being swept along or away by moving water such as breaking waves on a shoreline in a fashion similar to what happens when one hoses down a driveway or sidewalk with a swift stream of water.

LAKE LEVELS: the mean elevation above sea level of Lake Michigan fluctuates irregularly from year to year and from month to month within a year depending upon climate conditions in the region. Average seasonal patterns show low winter levels and high summer levels. The probable maximum monthly elevation and the low-water datum 581.2 and 576.8 feet respectively for Lakes Michigan-Huron.

LITTORAL DRIFT: the bottom sediments moved in the littoral or near-shore zone under the influence of waves and currents. Direction of this movement or littoral transport, depends on wind and wave directions.

SAND BARS OR SHOALS: sometimes called barrier bars or beaches, these are accumulations of sand formed from bottom materials and lying parallel to the shoreline in the shallow water near-shore zone. Bars have crests above water level, however, in Lake Michigan, such deposits often have crests just below lake level and are called shoals.

SHORELINE: the line forming the intersection of the water with the shore. The location of this line will vary depending upon lake level elevation.

SHORELINE EROSION: the wearing away of the shoreland (beach, cliff or dune) by the action of wind, water, gravity, or a combination thereof. Lake Michigan shoreline erosion is most often a combination of wind-driven waves beating upon the shore and forming littoral currents, and of high lake levels.

SLUMPING: a slow to moderately rapid type of downslope gravity movement by which masses of earth material slide downward and outward producing a scarp along the back of the slumped mass with subsidence at the top of the mass. The slumping along Lake Michigan is usually caused by oversteepening of the base of the slope by wave action.

SURF (BREAKER) ZONE: the near-shore, shallow-water zone where waves "break" and the water rushes up onto the shore as the water ceases moving in circular or elliptical orbits.

SHORELINE EROSION

In locations along the coasts of North America and Europe including the shores of the Great Lakes, cliffs are being eroded back in poorly-consolidated glacial deposits. In contrast to the slow process of shoreline erosion in the hard, well-consolidated varieties of bedrock, these cliffs are easily undermined and undergo very rapid erosion and landward retreat. The natural processes that cause shoreline erosion; and the means for eliminating or reducing the erosion will be discussed in this chapter as they relate to the coastline of Lake Michigan. It will be useful to refer back to the discussion of geologic processes in the shorezone presented in chapter one.

Fluctuations of Lake Level

Some spectacular changes in lake level occur suddenly. These short-period fluctuations result from meteorological conditions such as sudden high winds and sharp differential barometric pressures (see the discussion of seiches in chapter one), and last for only a few minutes to a few hours. The maximum such temporary rise recorded in the Great Lakes was 8.4 feet of Lake Erie in 1954.[1] Also in 1954, a seich of eight feet reached Montrose Harbor in Chicago.[2] However, it is the longer-period fluctuations that play a more significant role in shoreline erosion. The levels follow a seasonal pattern with highs in summer and lows in winter or early spring and this type of fluctuation averages 1.1 feet on Lakes Huron and Michigan (essentially a single body of water with respect to lake levels).

The levels of the Great Lakes also fluctuate from year to year as a result of variations in climate. Among the principal variables in these fluctuations are: (1) precipitation on the lake and the land surface drianed to the lake; (2) evaporation; and (3) flow in the rivers draining the lakes and connecting them with the other Great Lakes water bodies (Figure 1). Over the past century, Lake Michigan has fluctuated overall some 4.5 feet based on the difference recorded between the high and low monthly mean averages of lake level.[3] In summary then, Lake Michigan maintains lake levels for several months at a time, levels which vary through a range of 4.5 feet about its

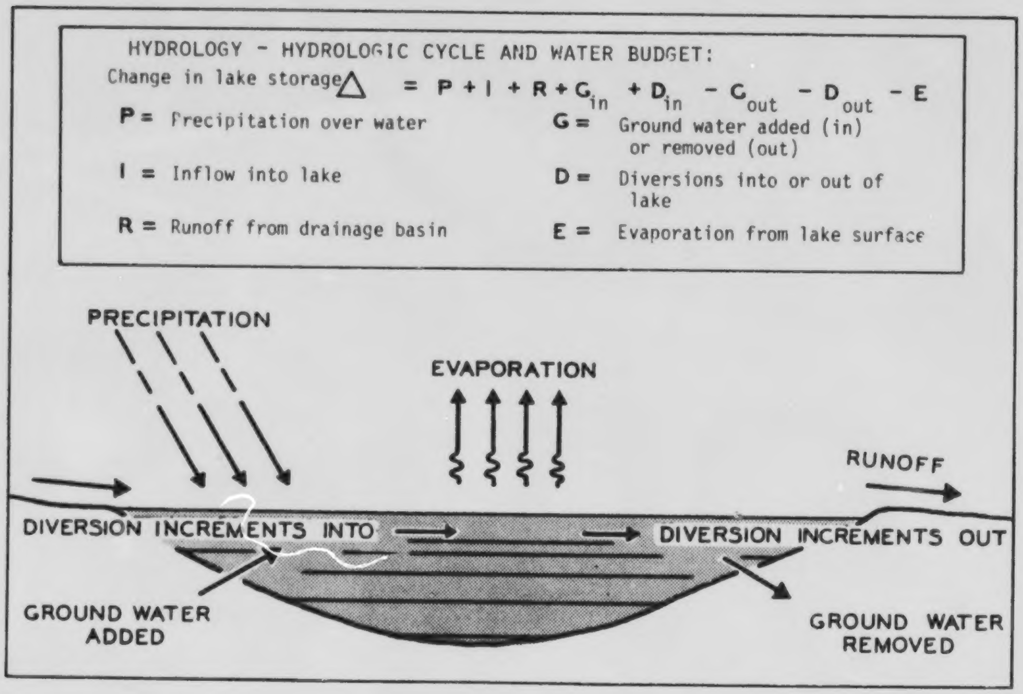

HYDROLOGY - HYDROLOGIC CYCLE AND WATER BUDGET:
Change in lake storage $\Delta = P + I + R + G_{in} + D_{in} - G_{out} - D_{out} - E$
P = Precipitation over water
G = Ground water added (in) or removed (out)
I = Inflow into lake
D = Diversions into or out of lake
R = Runoff from drainage basin
E = Evaporation from lake surface
PRECIPITATION
EVAPORATION
RUNOFF
DIVERSION INCREMENTS INTO
DIVERSION INCREMENTS OUT
GROUND WATER ADDED
GROUND WATER REMOVED

FIGURE 1. DIAGRAM ILLUSTRATING SEASONAL AND ANNUAL LAKE LEVEL FLUCTUATIONS: CHANGES IN LAKE STORAGE RESULT FROM CHANGES IN THE VARIABLES SHOWN IN THE EQUATION IN THE BOX ABOVE THE LAKE DIAGRAM (AFTER GUTSCHICK AND GONSIEWSKE, 1976).

MEAN ELEVATION. STORMS PRODUCE TEMPORARY ADDITIONAL CHANGES WHICH EXTEND THIS VERTICAL RANGE CONSIDERABLY IN THE COASTAL ZONES.

FIGURE 2 DEPICTS THE MAJOR PERIODS OF BOTH HIGH AND LOW LAKE LEVELS ON LAKE MICHIGAN BETWEEN 1925 AND 1975. NOTE THAT PERIODS OF LOW LAKE LEVEL EXISTED DURING THE DECADES OF THE 1930'S, THE LATE 1950'S, AND EARLY 1960'S. THESE WERE PERIODS WHEN BEACHES WERE WIDE AND ACTIVELY ACCUMULATING SAND, SAND DUNES WERE FORMING, AND SHORELINE EROSION GENERALLY WAS OF MINOR CONCERN. IN CONTRAST, FIGURE 2 ILLUSTRATES THAT THE LATE 1920'S, THE EARLY 1950'S, AND THE PRESENT SINCE 1969, HAVE BEEN PERIODS OF UNUSUALLY HIGH LAKE LEVELS. AT THESE TIMES, BEACHES HAVE BEEN NARROW OR NON-EXISTENT, AND BOTH CLIFFS AND SAND DUNES HAVE BEEN SUBJECTED TO EPISODES OF SEVERE SHORELINE EROSION. THUS, SHORELINE EROSION RESULTING FROM NATURAL PHENOMENA, CORRELATES CLOSELY WITH PERIODS WHEN THE LEVEL OF LAKE MICHIGAN IS HIGH.

OUR ABILITY TO PREDICT LAKE LEVELS IS ONLY AS GOOD AS OUR ABILITIES TO PREDICT THE CLIMATE AND ANY PERIODICITY OR CYCLICAL NATURE OF THAT CLIMATE. THE INTERNATIONAL GREAT LAKES LEVEL BOARD IN 1973 CONCLUDED THAT A CENTURY OF RECORDS DO NOT REVEAL ANY REGULAR, PREDICTABLE CYCLE. HOWEVER, MORE RECENT STUDIES BY COHN IN 1975 REVEAL-

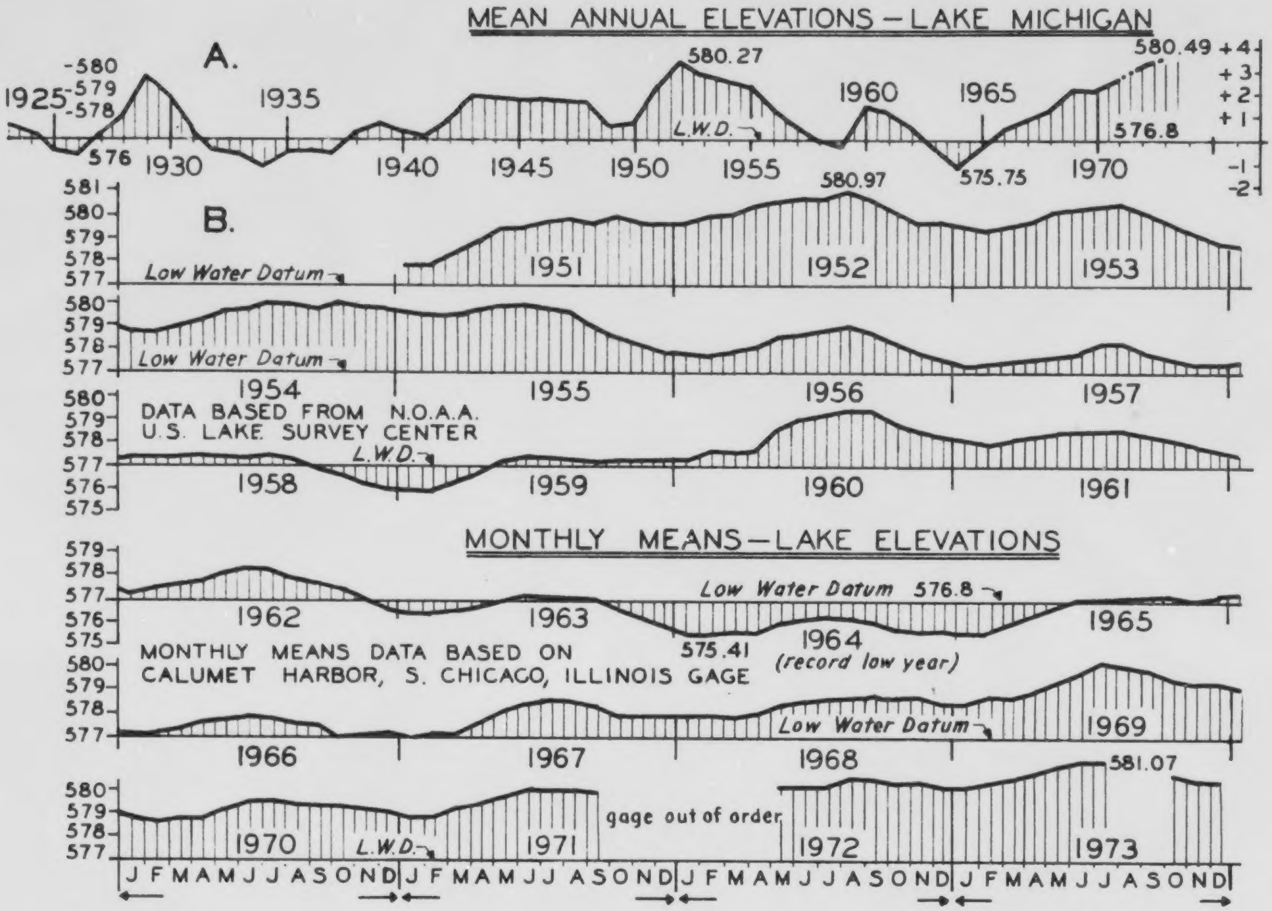


FIGURE 2. MEAN ANNUAL AND MONTHLY ELEVATIONS OF LAKE MICHIGAN, 1925 TO 1973 (FROM GUTSCHICK AND GONSIEWSKI, 1976).

ED PROMINENT CYCLES OF 1, 11, 22, AND 36 YEARS WHICH HE THOUGHT ALLOWED FOR SOME PREDICTABILITY OF FUTURE HIGH WATER LEVELS.[4]

SHORELINE EROSION AND DEPOSITION PROCESSES

DYNAMIC GEOLOGICAL ACTIVITY TAKES PLACE AT THE BOUNDARIES BETWEEN THE GREAT SPHERES OF THE EARTH: LAND, WATER, AND AIR. WHERE THIS BOUNDARY IS CALLED THE SHORELINE, IT INCLUDES: ON THE LANDWARD MARGIN: THE BEACH, DUNE, CLIFF, LOWLAND OR RIVER MOUTH; ON THE LAKEWARD MARGIN: THE LAKE BOTTOM AFFECTED BY WAVE AND NEAR-SHORE CURRENT ACTION, AND OF COURSE, THE ATMOSPHERE WHICH BOTH BLANKETS THE SYSTEM AND IS A PART OF IT. THE PROCESSES ALONG THE SHORELINE ARE BOTH EROSIONAL AND DEPOSITIONAL WITH VARYING INTERVALS EXISTING OF RELATIVE TEMPORARY STABILITY BETWEEN TIMES OF ACTIVE EROSION OR ACTIVE DEPOSITION. WE HAVE DISCUSSED WAVES AND WINDS, THE AGENTS OF EROSION AND DEPOSITION, AND THE FEA-

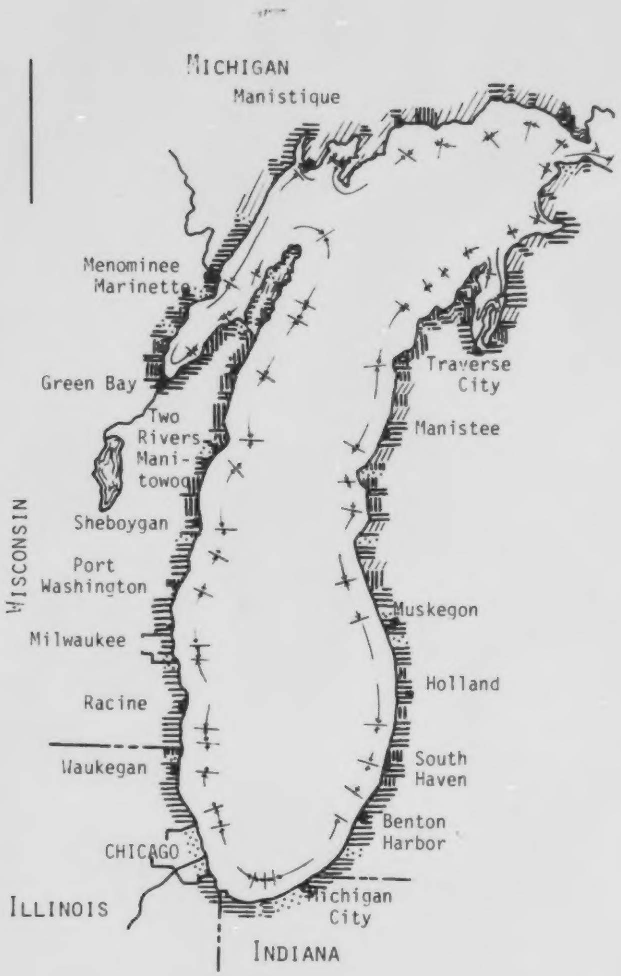

MICHIGAN
Manistique
Menominee
Marinette
Green Bay
Two Rivers
Mani-towoc
Sheboygan
Port Washington
WISCONSIN
Milwaukee
Racine
Waukegan
CHICAGO
ILLINOIS
INDIANA
Michigan City
Benton Harbor
South Haven
Holland
Muskegon
Manistee
Traverse City
SHORELAND USES
ALL PUBLIC LANDS AND BUILDINGS, RESIDENTIAL, COMMERCIAL AND INDUSTRIAL DEVELOPMENT
AGRICULTURAL AND UNDEVELOPED LANDS
RECREATION, INCLUDING FISH AND GAME AREAS
FOREST
SHORE TYPES
A ARTIFICIAL FILL AREA
HBE ERODIBLE HIGH BLUFF, 30 FT OR HIGHER
HBN NON-ERODIBLE HIGH BLUFF, 30 FT OR HIGHER
LBE ERODIBLE LOW BLUFF, LESS THAN 30 FT HIGH
LBN NON-ERODIBLE LOW BLUFF, LESS THAN 30 FT HIGH
HD HIGH SAND DUNE, 30 FT OR HIGHER
LD LOW SAND DUNE, LESS THAN 30 FT HIGH
PE ERODIBLE LOW PLAIN
PN NON-ERODIBLE LOW PLAIN
W WETLANDS

FIGURE 3. SHORELANDS OF LAKE MICHIGAN AND THEIR SUSCEPTIBILITY TO EROSION (FROM APP. 12: SHORE USE AND EROSION, GREAT LAKES BASIN FRAMEWORK STUDY, GLBD, 1975).

TURES THAT THEY PRODUCE IN CHAPTER ONE. HOWEVER, THE FOLLOWING DISCUSSION ENDEAVORS TO FOCUS ATTENTION ON EROSION ALONG THE LAKE MICHIGAN SHORELINE.

THE TYPE OF COASTAL TOPOGRAPHY, THE LEVEL OF THE LAKE, THE NATURE OF THE STORMS, AND THE COMPOSITION OF THE COASTAL EARTH MATERIALS ARE SIGNIFICANT DETERMINING FACTORS AFFECTING SHORELINE EROSION PROCESSES AND RATES. THE COASTS SURROUNDING LAKE MICHIGAN HAVE EXTENSIVE REACHES OF HIGH DUNES AND BLUFFS. THE BLUFFS ARE DEVELOPED ON STEEPLY INCLINED LAKEWARD FORESLOPES OF UNCONSOLIDATED EARTH MATERIALS, MOSTLY GLACIAL TILLS AND, TO A LESSER EXTENT, FINE-GRAINED LAKE CLAYS. THE SAND DUNES RANGE FROM SMALL FOREDUNES AT THE HEAD OF THE BEACH TO TOWERING, MANY MAN-MADE STRUCTURES. WAVES TEN FEET HIGH CRASHING ON THE SHORELAND HAVE FORCES WHICH HAVE MEASURED AS HIGH AS 1,200 POUNDS PER SQUARE FOOT. RATES OF EROSION PRODUCED BY THESE CRASHING WAVES DEPEND UPON: THE FORM OF THE BEACH AND ITS EXPOSURE TO THE WIND; THE TOPOGRAPHY OF THE COAST (WHETHER LOW AND DUNED OR STEEP AND CLIFFED); OFF-SHORE BOTTOM TOPOGRAPHY; LAKE LEVEL CHANGES, CURRENTS ALONG THE SHORE; AND THE AVAILABILITY OF EARTH MATERIALS IN THE LAKE.

EROSION AND DEPOSITION ARE RELATED TO THE ENERGY/WORK-LOAD BALANCE OF THE WAVES AND CURRENTS. WAVE ENERGY (E), DEPENDS ON THE WAVE LENGTH (L), WAVE HEIGHT

(H), AND WATER WEIGHT (w):

$$E = \frac{wLH^2}{8}$$

WAVE HEIGHT DEPENDS ON PREVAILING WIND STRENGTH AND DURATION PATTERNS, FETCH (DISTANCE OVER WHICH THE WIND BLOWS) AND CONFIGURATION OF THE SHORE BOTTOM (DISCUSSED BELOW). WAVE STEEPNESS, (H/L), IS THE CRITICAL FACTOR AS HEIGHT IS THE MAJOR FACTOR IN THE WAVE ENERGY EQUATION ABOVE. HIGH ENERGY, EROSIVE WAVES ARE STEEP; THEY ARE HIGH RELATIVE TO THEIR LENGTH. CONSTRUCTIONAL WAVES TEND TO BUILD A BEACH AND ARE LONG AND LOW. AS THE WAVE ENTERS SHALLOW WATER IT "BOTTOMS", I.E., IT BEGINS TO FEEL THE FRICTIONAL EFFECTS OF THE BOTTOM TOPOGRAPHY. THE WAVE LENGTH DECREASES AND THE WAVE HEIGHT INCREASES UNTIL IT BECOMES TOO STEEP TO HOLD ITS FORM UNDER THE PULL OF GRAVITY AND IT CRASHES FORWARD OR "BREAKS", AND ITS ENERGY IS DISSIPATED ON THE SHORE (FIGURE 4).

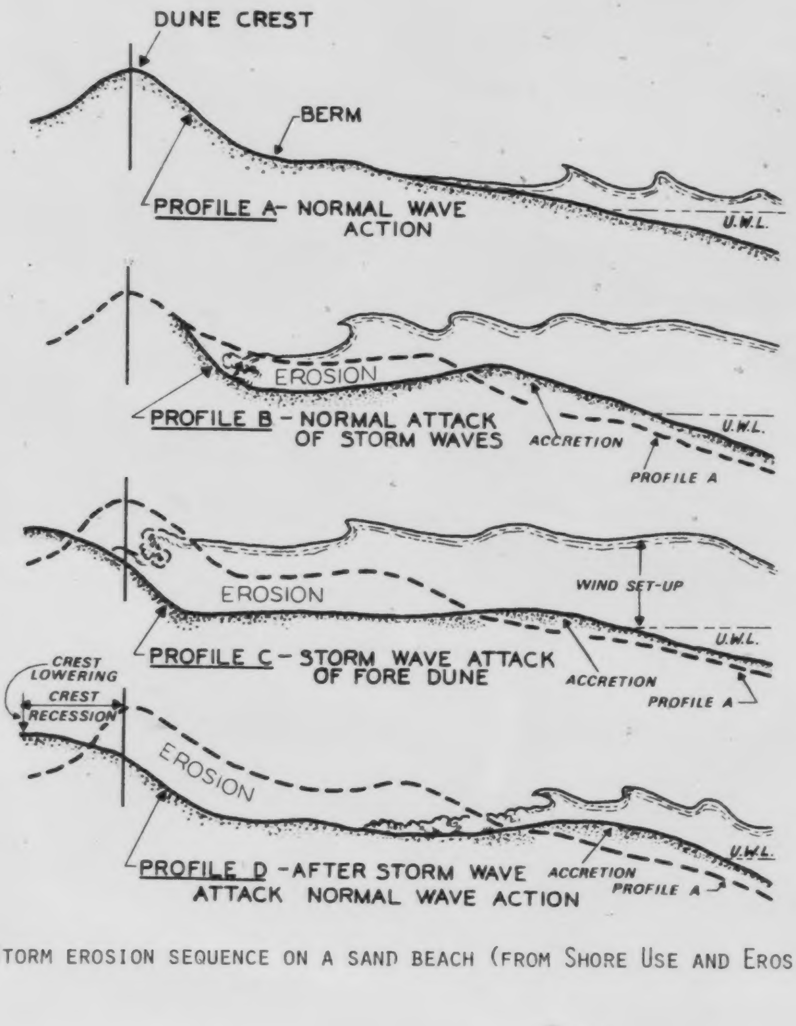

DUNE CREST
BERM
PROFILE A- NORMAL WAVE ACTION
U.W.L.
EROSION
PROFILE B - NORMAL ATTACK OF STORM WAVES
ACCRETION
PROFILE A
WIND SET-UP
EROSION
U.W.L.
PROFILE C - STORM WAVE ATTACK OF FORE DUNE
ACCRETION
PROFILE A
CREST LOWERING
CREST RECESSION
EROSION
U.W.L.
PROFILE D -AFTER STORM WAVE ATTACK NORMAL WAVE ACTION
ACCRETION
PROFILE A

FIGURE 4. STORM EROSION SEQUENCE ON A SAND BEACH (FROM SHORE USE AND EROSION, APPENDIX 12).

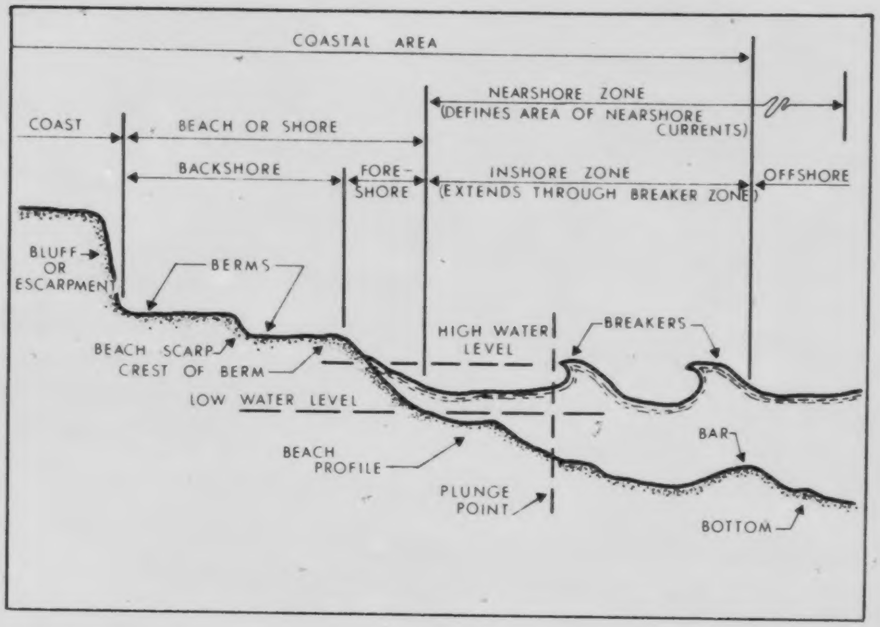

COASTAL AREA
NEARSHORE ZONE
(DEFINES AREA OF NEARSHORE CURRENTS)
COAST
BEACH OR SHORE
BACKSHORE
FORE-SHORE
INSHORE ZONE
(EXTENDS THROUGH BREAKER ZONE)
OFFSHORE
BLUFF OR ESCARPMENT
BERMS
HIGH WATER LEVEL
BREAKERS
BEACH SCARP
CREST OF BERM
LOW WATER LEVEL
BEACH PROFILE
BAR
PLUNGE POINT
BOTTOM

Figure 5. Beach Profile-Related Terms (after App. 12, Great Lakes Basin Framework Study).

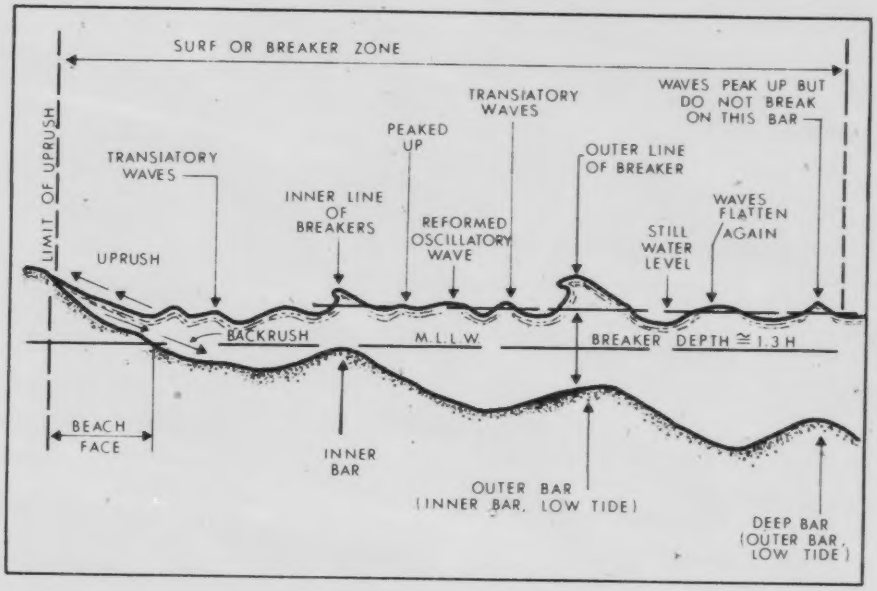

SURF OR BREAKER ZONE
LIMIT OF UPRUSH
TRANSIATORY WAVES
PEAKED UP
TRANSIATORY WAVES
WAVES PEAK UP BUT DO NOT BREAK ON THIS BAR
OUTER LINE OF BREAKER
INNER LINE OF BREAKERS
REFORMED OSCILLATORY WAVE
STILL WATER LEVEL
WAVES FLATTEN AGAIN
UPRUSH
BACKRUSH
M.L.L.W.
BREAKER DEPTH ≅ 1.3 H
BEACH FACE
INNER BAR
OUTER BAR (INNER BAR, LOW TIDE)
DEEP BAR (OUTER BAR, LOW TIDE)

Figure 6. Schematic Diagram of Waves in the Breaker Zone (after A-p. 12, Great Lakes Basin Framework Study)

Figure 5 illustrates a Great Lakes coastal profile. In it, the beach, a relatively small landform, acts as a defense against the attack of the waves by reflecting, defracting, or refracting wave energies. The major erosional and depositional processes occur in the surf or extensively vegetated and stabilized dune complexes extending inland.

At times of low lake level, the dune-bluff systems are separated from the water's edge by relatively wide, sandy beaches with extensive low foredunes capping their landward margin. The destructive energy of storm waves are dissipated on the beaches and rarely reach the steeper landforms. However, as discussed above at times of high lake level, beaches are narrow and foredunes are not evolving. It is at these times that shoreline erosion is severe.

The unconsolidated nature of the earth materials, the sediments, comprising the Lake Michigan coast make them susceptible to high rates of erosion. Storm waves crash against the bases of these steep landforms eroding the relatively soft materials and causing the loose or poorly consolidated sediments that are about to slump into the lake to be carried away by the currents. Figure 3 illustrates the types of shoreland topography subject to erosion in the Lake Michigan region. Estimates indicate that 1.050 miles of Lake Michigan shorelands are erodible while only 313 miles of coast are non-erodible or are artificial fill areas.[5] Figure 3 reveals that the large, erodible high dunes (HD) extend from the Indiana Dunes National Lakeshore discontinuously along the eastern lakeshore to the Leelanous Peninsula and that erodible bluffs line both eastern and western shores of the lake (HBE and LBD). The non-erodible bluff areas (HBN and LBN) are limited generally to Michigan's upper Peninsula portion of the lake and the northern parts of the Door Peninsula in Wisconsin.

Waves are the most important agent of erosion and deposition along the shore. The hydraulic action of the waves is a powerful force. These pressures are enough to move large blocks of rock from cliffs and to disrupt breaker zone (Figure 6). The erosive energy of a wave is a function of wave height and water depth with energy greatest in deep water with steep waves. The shoreline erosional effects of this energy occur in the surf or breaker zone from the point where the waves begin to break to the limit of run-up of the waves on the shore.

The bottom topography also is an important factor in the shoreline erosion process. Much of the energy of the onushing deep-water waves is dissipated against this submerged surface. The transmitted energies generate processes which build off-shore bars in front of the beach which, in turn, intercept much of the erosional energy of subsequent waves (Figure

6). THE FLAT BEACHES AND GENTLE BOTTOM TOPOGRAPHIES OF THE EASTERN AND SOUTHEASTERN LAKE MICHIGAN SHORES HAVE AS MANY AS THREE OFF-SHORE BARS, WHILE THE MORE STEEPLY SLOPED OFF-SHORE BOTTOM OF THE WESTERN SHORE GENERALLY HAS BUT ONE OFF-SHORE BAR. BEACHES WITH A STEEP APPROACH AND FEW OFF-SHORE BARS ALLOW THE SWELL, I.E., THE BREAKING WAVES--TO APPROACH THE SHORE WITHOUT BEING SLOWED OR CHANGED AND TO CRASH VIGOROUSLY ON THE BEACH FACE. THESE ARE CALLED PLUNGING BREAKERS. IN THE COASTAL REACHES WHERE THE BOTTOM TOPOGRAPHY SLOPES GENTLY AWAY FROM THE BEACH AND MULTIPLE OFF-SHORE SAND BARS EXIST, SHOALING OCCURS SO THAT LARGE WAVES OFTEN BREAK AND REFORM A NUMBER OF TIMES BEFORE REACHING THE BEACH.

THE SMALL WAVES CARRY SAND SHOREWARD AND PRODUCE SAND BEACH AND SAND BAR GROWTH. LARGE WAVES, HOWEVER, CRASH SHOREWARD AND WORK TO STEEPEN THE BEACH AND OFF-SHORE PROFILE AND RESULT IN SAND BEING CARRIED AWAY INTO DEEPER LAKE WATERS. THE DIFFERENCE BETWEEN EROSIONAL AND DEPOSITIONAL WAVES ON LAKE MICHIGAN SHORES HAS BEEN DOCUMENTED BY FOX AND DAVIS IN 1973.[6] AS STORM SYSTEMS MOVE INTO THE LAKE MICHIGAN REGION (GENERALLY FROM NORTHWEST TO SOUTHEAST) STRONG WINDS BLOWING ONSHORE INCREASE WAVE HEIGHTS (FIGURE 7). THESE ARE THE STEEP WAVES WHICH CAUSE BEACH, BLUFF AND DUNE EROSION AND MOVE SEDIMENT OFF-SHORE TO FORM UNDERWATER SAND BARS. AS THE STORM SUBSIDES AND PASSES TO THE EAST, THE WIND SHIFTS, BLOWING OFFSHORE, AND THERE IS A POST-STORM RECOVERY. WAVES APPROACH THE SHORE WHICH ARE LOW IN HEIGHT AND ENERGY AND THEY BREAK GENTLY OVER THE OFF-SHORE BAR MOVING IT LANDWARD AS SOME OF THE BEACH IS RECOVERED. BUT, THERE IS A NET LOSS OF SEDIMENT OVER ALL AS A RESULT OF THE STORM.

THUS, SHORELINE EROSION CORRELATES CLOSELY WITH STORM ACTIVITY. INDEED, THE EROSION CAN BE VIEWED AS EPISODIC, A PRODUCT OF CLIMATE, OFF-SHORE AND ON-SHORE TOPOGRAPHY, EARTH MATERIALS (SEDIMENTS), AND LAKE LEVEL ELEVATION.

LAKE CURRENTS AND LONGSHORE DRIFTING

WAVE GENERATED CURRENTS TRANSPORT BEACH MATERIALS AND COMPRISE AN IMPORTANT FACTOR TO THE EROSION AND DEPOSITION PROCESSES OF LAKE MICHIGAN'S COASTAL AREAS. CURRENTS ARE GENERATED WHEN WAVES APPROACH THE SHORE OBLIQUELY. IF THE SHORE IS A STRAIGHT ONE, THE CUMULATIVE EFFECT OF THE WAVES BREAKING IN A DIRECTION OBLIQUE TO THE SHORE IS TO GENERATE AN "ALONG SHORE" OR "LITTORAL CURRENT", ONE WHICH MOVES PARALLEL TO THE SHORELINE AND WHICH TRANSPORTS SEDIMENTS ALONG THE SHORE -- A LITTORAL DRIFT. ANOTHER PROCESS BY WHICH SEDIMENT IS MOVED ALONGSHORE IS BEACH DRIFT. AS A WAVE BREAKS OBLIQUELY ON THE SHORE ITS RUN-UP OR SWASH CARRIES SEDIMENT PARTICLES DIAGONALLY UP THE BEACH. AS THE BACKWASH OF THE WATER RETURNS TO THE LAKE, SEDIMENT PARTICLES ARE CARRIED

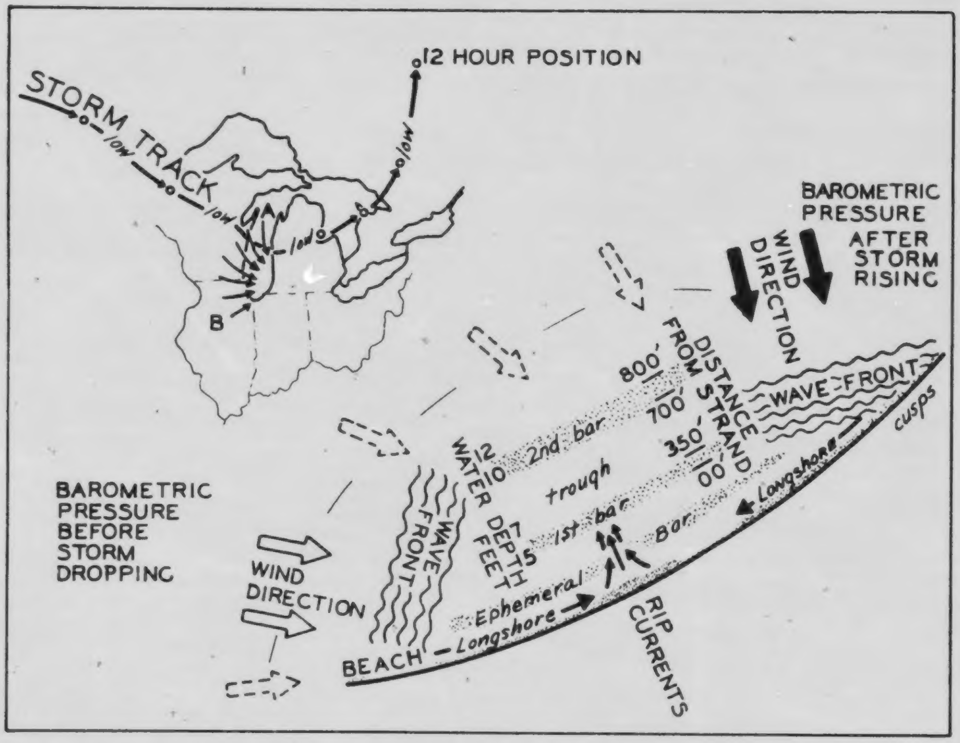
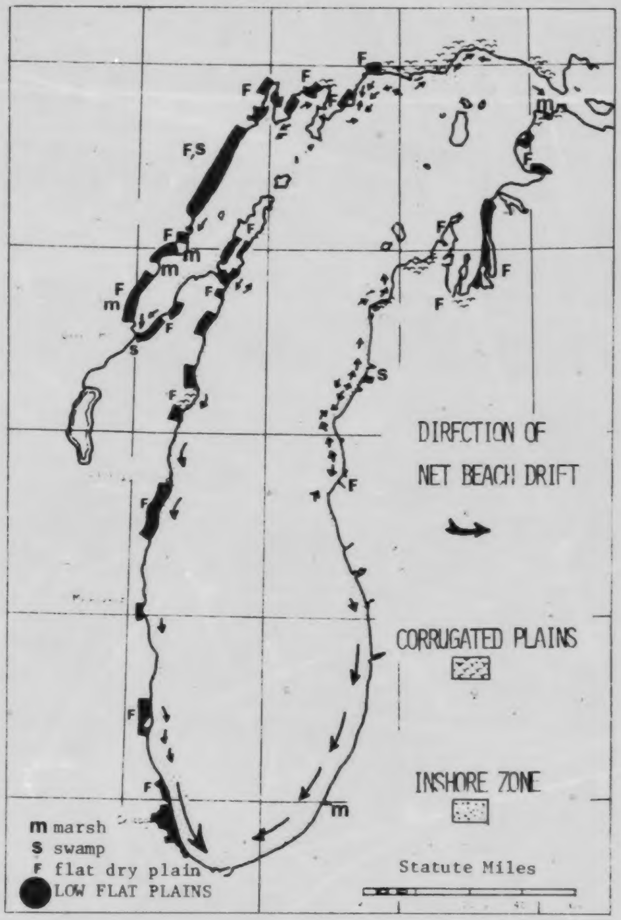

12 HOUR POSITION
STORM TRACK
low
low
low
low
A
B
BAROMETRIC PRESSURE AFTER STORM RISING
WIND DIRECTION
DISTANCE FROM STRAND
800'
700'
350'
100'
WAVE FRONT
cusps
Longshore
2nd bar
trough
1st bar
Bar
12
10
7
5
WATER DEPTH FEET
WAVE FRONT
BAROMETRIC PRESSURE BEFORE STORM DROPPING
WIND DIRECTION
Ephemeral
Longshore
BEACH
RIP CURRENTS

FIGURE 7. MAP SHOWING CLIMATIC AND GEOLOGIC PROCESSES RESPONSIBLE FOR EROSION AND DEPOSITION ALONG THE SHORE OF LAKE MICHIGAN (AFTER DAVIS AND FOX, 1971, AND FOX AND DAVIS, 1973).

LAKEWARD IN A PATH PERPENDICULAR TO THE COAST. AN OVERALL ZIG-ZAG MOVEMENT OF BEACH SEDIMENT OCCURS AND A NET DOWN BEACH OR DOWN-CURRENT MIGRATION OF THE BEACH OCCURS.

THE BEACH SYSTEM DEVELOPS A STEADY-STATE, OR DYNAMIC EQUILIBRIUM CONDITION WHICH INVOLVES A DELICATE BALANCE BETWEEN THE SAND DEPOSITED AND THE SAND ERODED. THE BEACH AND ITS ASSOCIATED FEATURES ARE A DYNAMIC, EVER-CHANGING FEATURE. THE FORM AND SIZE OF THE DEPOSIT, THE SAND BEACH, REMAINS CONSTANT IF THE SAND CARRIED AWAY DOWN-CURRENT OR DOWN-DRIFT IS MATCHED BY THE SAND CARRIED IN AND DEPOSITED FROM THE UP-CURRENT DIRECTION. IF THE TRANSPORT SYSTEM IS DISTURBED SO THAT MORE SAND ARRIVES THAN IS REMOVED, THE BEACH GROWS IN SIZE AND MAY CHANGE IN SHAPE. HOWEVER, IF MORE SAND IS REMOVED THAN ARRIVES, THEN EROSION OCCURS. NATURAL CHANGES IN THE DYNAMIC SYSTEM CAN CAUSE SHORELINE EROSION; SUCH CHANGES ARE RISING LAKE LEVEL AND THE ARRIVAL OF STORMS. UNFORTUNATELY, A MOST DISTURBING ELEMENT HAS BEEN ADDED ALONG THE LAKE MICHIGAN SHORELINE, MAN. HUMAN ACTIVITY HAS EFFECTED CHANGES IN LITTORAL DRIFT AND BEACH DRIFT PATTERNS. FIGURES 8 AND 9 DEPICT THE LONGSHORE BEACH DRIFT AND CURRENTS FOR LAKE MICHIGAN.

Figure 8. Direction of net longshore drift in Lake Michigan (from Hands, 1970).


F
F
F
F,S
F
m
F
m
m
F
m
F
S
F
F
S
F
F
F
F
F
F
F
m
DIRECTION OF NET BEACH DRIFT
CORRUGATED PLAINS
INSHORE ZONE
m marsh
s swamp
F flat dry plain
LOW FLAT PLAINS
Statute Miles

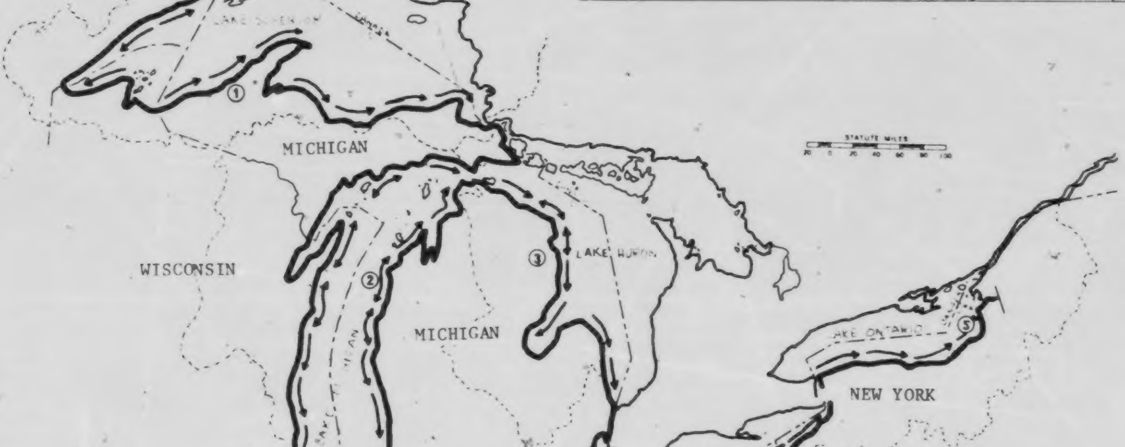

LAKE SUPERIOR
①
MICHIGAN
STATUTE MILES
②
③
LAKE HURON
WISCONSIN
MICHIGAN
LAKE MICHIGAN
LAKE ONTARIO
⑤
NEW YORK
LAKE ERIE
ILLINOIS
④
INDIANA
OHIO

Figure 9. Net Direction of Littoral Transport, United States Shorelands of the Great Lakes (from App. 12, Great Lakes Basin Framework Study, 1975).

THE EFFECTS OF MAN-MADE COASTAL STRUCTURES

AS STATED ABOVE, SHORELINE EROSION IS CAUSED PRINCIPALLY BY STORM-INDUCED WAVE ACTION AND ASSOCIATED LONGSHORE CURRENTS AND IS PARTICULARLY CRITICAL DURING PERIODS OF HIGH LAKE LEVELS WHEN BEACHES ARE SUBMERGED. CRITICAL SHORELAND EROSION AREAS HAVE BEEN IDENTIFIED ON THE BASIS OF "REACHES OF SHORELINE WHERE THE EROSION RATE, CONSIDERED IN CONJUNCTION WITH ECONOMIC INDUSTRIAL, RECREATIONAL, AGRICULTURAL, NAVIGATIONAL, DEMOGRAPHIC, ECOLOGICAL, AND OTHER RELEVANT FACTORS, INDICATES THAT ACTION TO HALT EROSION MAY BE JUSTIFIED."[7] IN SHORT, JUSTIFICATION IS BASED ON THE LAND/WATER USES OF THE COASTAL RESOURCES AND THE IMPORTANCE PLACED BY SOCIETY ON THE EROSIONAL IMPACT ON HUMAN ACTIVITIES AND INVESTMENT.

AS WITH MANY OTHER NATURAL PROCESSES, THE WORK OF WAVES, ALONG THE COAST CREATES PROBLEMS FOR MAN. AS HE DEVELOPS HARBORS, LANDFILLS, AND A MULTITUDE OF OTHER COASTAL MODIFICATIONS, HE TRIES TO STABILIZE THE COASTAL AREA. BUT THIS ACTIVITY COMES INTO DIRECT CONFLICT WITH THE NATURAL FORCES SEEKING TO CHANGE THE SHORE. GROINS, JETTIES, AND SEAWALLS ARE CONSTRUCTED TO FACILITATE THE LAND USES OF THE COASTAL RESOURCES BY CONTROLLING THE WAVES. GROINS ARE WALLS CONSTRUCTED ON THE BEACH AND EXTENDED PERPENDICULARLY OUT INTO THE LAKE TO TRAP THE SEDIMENTS CARRIED BY THE BEACH AND LITTORAL DRIFT. THEIR CONSTRUCTION OFTEN RESULTS IN A DESIRED SAND BEACH ACCUMULATION UP-CURRENT FROM THE STRUCTURE; HOWEVER, CONCURRENTLY, EROSION AND LOSS OF BEACH OCCUR DOWN-CURRENT FROM THE STRUCTURE AT HIGH LAKE LEVELS. JETTIES ARE SIMILAR TO GROINS BUT PLACED AT THE SIDES OF AN INLET TO STOP THE TRANSPORT OF SEDIMENT INTO THE INLET. THE INTENT IS TO KEEP THE INLETS OPEN OR FREE FROM SEDIMENT. THE NET EFFECT DOWN CURRENT OF JETTIES IS SIMILAR TO THAT FROM GROINS; BEACH EROSION DOWNDRIFT. SEAWALLS ARE COMPRISED OF VARIOUS MATERIALS LAID DOWN PARALLEL TO THE SHORELINE IN AN ATTEMPT TO ARMOR THE COAST FROM THE ONSLAUGHT OF THE WAVES. DURING HIGH WATER STAGES SUCH STRUCTURES CAN HAVE THE EFFECT OF PROTECTING THE ADJACENT COAST BUT THEY ALSO ACCELERATE EROSION IN UNPROTECTED REACHES DOWN-CURRENT FROM THE SEAWALL.

LAKE MICHIGAN COASTAL LAND USES

LAKE MICHIGAN IS THE ONLY GREAT LAKE SITUATED ENTIRELY WITHIN THE UNITED STATES. EXTENDING NORTH-SOUTH FOR SOME 300 MILES, IT IS AT ONCE A TRANSPORTATION CORRIDOR AND THE MIDWEST'S MOST SIGNIFICANT TRANSPORTATION BARRIER. MANY MAJOR URBAN CENTERS INCLUDING CHICAGO, ILLINOIS; MILWAUKEE AND GREEN BAY, WISCONSIN; HAMMOND, EAST CHICAGO, AND GARY, INDIANA; AND MUSKEGAN, MICHIGAN ARE SITUATED ON THE SHORELANDS OF THE LAKE. SMALLER URBAN CENTERS ARE MANITOWOC, SHEBOYGAN, RACINE AND KENOSHA, WISCONSIN; THE CHICAGO suburbs of Illinois; and Benton Harbor - St. Joseph, Holland, Grand Haven, Manistee, Taveral City, Menominee, Escanaba, and Manistique, Michigan. With the exception of Michigan's Upper Peninsula, some portions of northern Wisconsin, and Michigan's northern Lower Peninsula, Lake Michigan's shorelands are used extensively for residential, commercial, industrial and recreational developments and for agriculture. Table 1 presents the distribution of shoreland uses, ownership, and types of shoreland topography. Commercial and industrial uses are concentrated along the Indiana-Illinois reaches, however, these uses give way to permanent and seasonal residential land uses north-

Table 1. Lake Michigan Shoreland Use, Ownership, and Shore Type

	Wisconsin	Michigan	Illinois	Indiana	Total
Shoreland Use					
Residential	148.9	292.2	15.0	5.5	461.6
Industrial and commercial	12.9	24.7	10.5	21.8	69.9
Public lands and buildings	8.8	3.5	8.0	0.6	20.9
Agriculture and undeveloped	103.8	176.1	0.6	0.1	280.6
Recreation	54.4	58.5	30.9	17.0	160.8
Wildlife preserves	18.2	0.0	0.0	0.0	18.2
Forest lands	60.0	290.0	0.0	0.0	350.0
Shoreland Ownership					
Federal	0.0	13.0	3.1	9.3	25.4
Non-Federal public	75.2	100.2	35.8	8.7	219.9
Private	331.8	731.8	26.1	27.0	1,116.7
Shore Types					
Artificial fill area	12.4	3.8	26.6	24.6	67.4
Erodible high bluff	95.4	157.3	20.9	0.0	273.6
Non-erodible high bluff	30.1	16.8	0.0	0.0	46.9
Erodible low bluff	28.0	90.9	0.0	0.0	118.9
Non-erodible low bluff	13.1	11.6	0.0	0.0	24.7
High sand dune	0.0	128.0	0.0	11.6	139.6
Low sand dune	16.4	48.7	0.0	8.3	73.4
Erodible low plain	77.0	192.5	17.5	0.5	287.5
Non-erodible low plain	58.4	115.1	0.0	0.0	173.5
Wetlands	14.2	80.3	0.0	0.0	94.5
Wetlands/erodible plain	51.8	0.0	0.0	0.0	51.3
Wetlands/erodible low bluff	10.2	0.0	0.0	0.0	10.2
Total Shore Miles	407.0	845.0	65.0	45.0	1,362.0

(from App. 12, Great Lakes Basin Framework Study, G.L.B.C., 1975) ward to Frankfort in Michigan and Sturgeon Bay in Wisconsin. Northward, agricultural and forestland uses predominate. Recreational land uses are extensive in all reaches with large expanses of sandy beaches and dunes on the eastern and southeastern shores. Of the 245 miles of publicly owned shoreland, 156 miles are Federal, State, and local parks and recreation areas.

Studies in the changes of shoreland use (Table 2) indicate that residential land-uses will diminish as will the agricultural, forested and undeveloped areas. Damages from projected shoreland erosion, however, will increase in residential areas and also in recreational areas (Table 3). Indeed, Curtis Larsen has hypothesized that shoreline erosion will increase over time because as more of the shoreline becomes protected behind seawalls or upcurrent from groins and jetties, the erosional forces will be concentrated on the remaining unprotected reaches (Larsen, 1976). This is, at the least, an interesting thought.

Table 4 lists 18 locations of authorized beach erosion control studies as of 1975. Obviously no singular method of control is suitable. Where industry and commerce are highly developed, permanent structural protection has been provided as part of the site preparation via extensive seawalls, jetties, and groins.

Table 2. Existing and Projected Shoreland Use - Lake Michigan

Shoreland Use	Miles of Shoreline			
	1970	1980	2000	2020
Industrial, Commercial, Public Buildings, and Lands	91	97	106	113
Residential	462	994	540	577
Public Parks, Recreation	161	172	188	195
Fish and Wildlife	18	18	18	18
Agriculture, Forest, and Undeveloped	630	581	510	459
Total	1,362	1,362	1,362	1,362

(from App. 12, Great Lakes Basin Framework Study, G.L.B.C., 1975)

Table 3. Existing and Projected Shoreland Damages - Lake Michigan, in thousands of dollars

Land Use	Potential Single Year Damages			
	1966	1980	2000	2020
Industrial, Commercial, Public Buildings, and Lands	1,685	2,110	2,769	2,855
Residential	21,536	32,841	56,282	56,216
Public Parks, Recreation	4,427	7,754	16,657	27,168
Agriculture, Forest, and Undeveloped	2,250	2,219	2,512	3,104
Total	29,898	44,924	78,220	89,343

(from App. 12, Great Lakes Basin Framework Study, G.L.B.C., 1975)

Low-cost shore protection is desired for the long reaches of shoreline used for residences which comprise much of the 130 miles of critically eroding Lake Michigan shoreline. This cost for residential protection alone was estimated at $65 million in 1975.[8] The recreational areas along the shoreline also contain extensive reaches where erosion is critical such as the Mount Baldy area of the Indiana Dunes National Lakeshore. A variety of approaches to the problem exist and are considered in a subsequent section. But, before such consideration, it is valuable to examine a few case studies.

Shoreline Erosion at the Indiana Dunes National Lakeshore

Severe shoreline erosion has occurred in the reach west of the Michigan City harbor structure over the past decade with the most severe erosion impacting the Mt. Baldy area of the Indiana Dunes National Lakeshore (Figure 10). The Corps of Engineers has commissioned extensive studies of the erosion and proposed a variety of solutions ranging from structural, such as groins and seawalls, to non-structural, such as zoning and structure setbacks. At present, the most favored alternative is the creation of a sand fill where the erosion is most severe. The sand is to be acquired from inland sites or as a sediment by-pass

TABLE 4. EXISTING AND AUTHORIZED FLOOD AND EROSION CONTROL PROJECTS

THERE ARE SEVEN AUTHORIZED BEACH EROSION CONTROL PROJECTS ON LAKE MICHIGAN. THE FOLLOWING IS A LIST OF LOCATIONS OF AUTHORIZED BEACH EROSION CONTROL STUDIES AND THE AUTHORITY UNDER WHICH THEY WERE AUTHORIZED:

(1) MILWAUKEE COUNTY SHORELINE, WISCONSIN, RESOLUTION
(2) ILLINOIS SHORE OF LAKE MICHIGAN, ILLINOIS, RESOLUTION
(3) INDIANA SHORELINE EROSION, INDIANA, RESOLUTION
(4) MICHIGAN CITY HARBOR, INDIANA, SECTION 111
(5) ST. JOSEPH HARBOR, MICHIGAN, SECTION 111
(6) HAGAR TOWNSHIP, MICHIGAN, SECTION 103
(7) SOUTH HAVEN HARBOR, MICHIGAN, SECTION 111
(8) HOLLAND HARBOR, MICHIGAN, SECTION 111
(9) GRAND HAVEN HARBOR, MICHIGAN, SECTION 111
(10) MUSKEGON HARBOR, MICHIGAN, SECTION 111
(11) WHITE LAKE HARBOR, MICHIGAN, SECTION 111
(12) PENTWATER HARBOR, MICHIGAN, SECTION 111
(13) LUDINGTON HARBOR, MICHIGAN, SECTION 111
(14) MANISTEE HARBOR, MICHIGAN, SECTION 111
(15) PORTAGE LAKE HARBOR, MICHIGAN, SECTION 111
(16) FRANKFORT HARBOR, MICHIGAN, SECTION 111
(17) EMPIRE, MICHIGAN, SECTION 103
(18) LELAND HARBOR, MICHIGAN, SECTION 111

(FROM APP:12: GREAT LAKES BASIN FRAMEWORK STUDY, 1975.

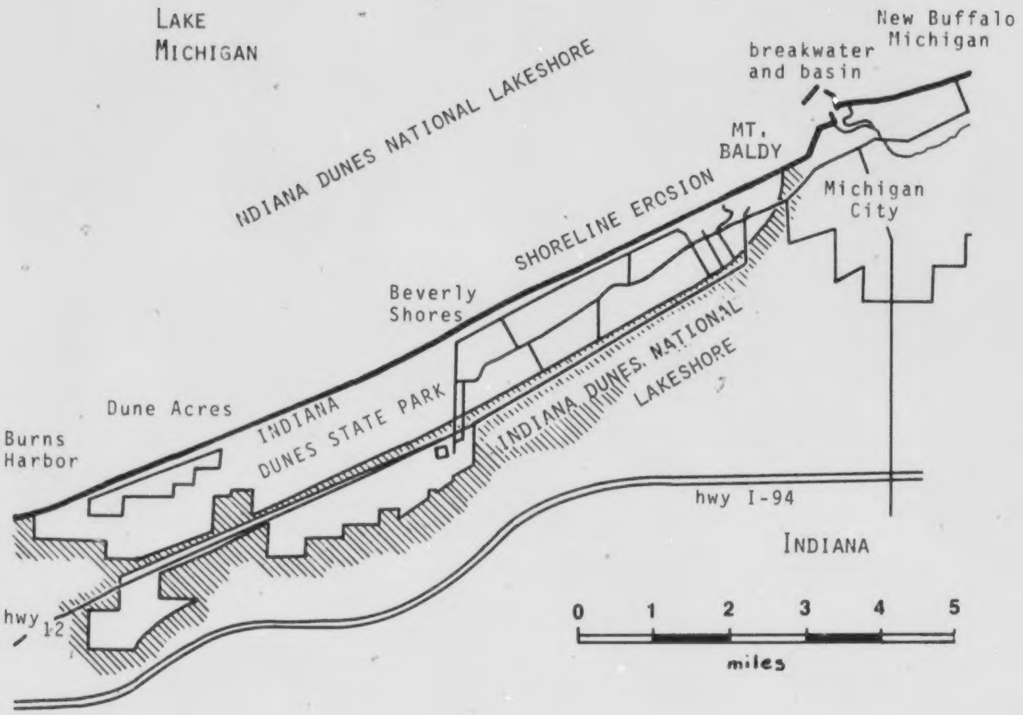

LAKE MICHIGAN
INDIANA DUNES NATIONAL LAKESHORE
New Buffalo Michigan
breakwater and basin
MT. BALDY
SHORELINE EROSION
Michigan City
Beverly Shores
Dune Acres
Burns Harbor
INDIANA DUNES STATE PARK
INDIANA DUNES NATIONAL LAKESHORE
hwy I-94
INDIANA
hwy 12
0
1
2
3
4
5
miles

FIGURE 10. EROSION AT THE INDIANA DUNES NATIONAL LAKESHORE. DEPOSITION OCCURS EAST OF THE HARBOR STRUCTURES AND EROSION IS ACCELERATED WEST OF THE SETTLES (AFTER GUTSCHICK AND GONSIEWSKI, 1976).

FROM DEPOSITS ACCUMULATING IN THE LAKE EAST OF THE MICHIGAN CITY HARBOR STRUCTURE.

STUDIES REVEAL THAT LITTORAL AND BEACH DRIFT ARE SUCH THAT SEDIMENT IS CARRIED SOUTH WESTWARD ALONG THE COASTLINE. THE MICHIGAN CITY HARBOR STRUCTURE, THEREFORE, COMBINES WITH HIGH LAKE LEVELS TO CREATE A CONDITION OF EXTENSIVE EROSION DURING STORM TIMES. IT HAS BEEN DETERMINED THAT 35 PERCENT OF THE EROSION RESULTS FROM THE CONDITION OF HIGH LAKE LEVEL AND 65 PERCENT FROM THE INTERCEPTION OF LITTORAL AND BEACH DRIFT BY THE HARBOR STRUCTURES. THE NET EFFECT HAS BEEN SEVERE BEACH AND DUNE EROSION FOCUSED PRIMARILY IN A NATIONAL PARK AREA.

SHORELINE EROSION BETWEEN ST. JOSEPH AND THE GRAND MERE LAKES, BERRIAN COUNTY, MICHIGAN

THE HIGH BLUFFS BETWEEN THE CITY OF ST. JOSEPH AND THE GRAND MERE LAKES ARE COMPRISED OF BEDDED DENSE CLAY, SANDS,

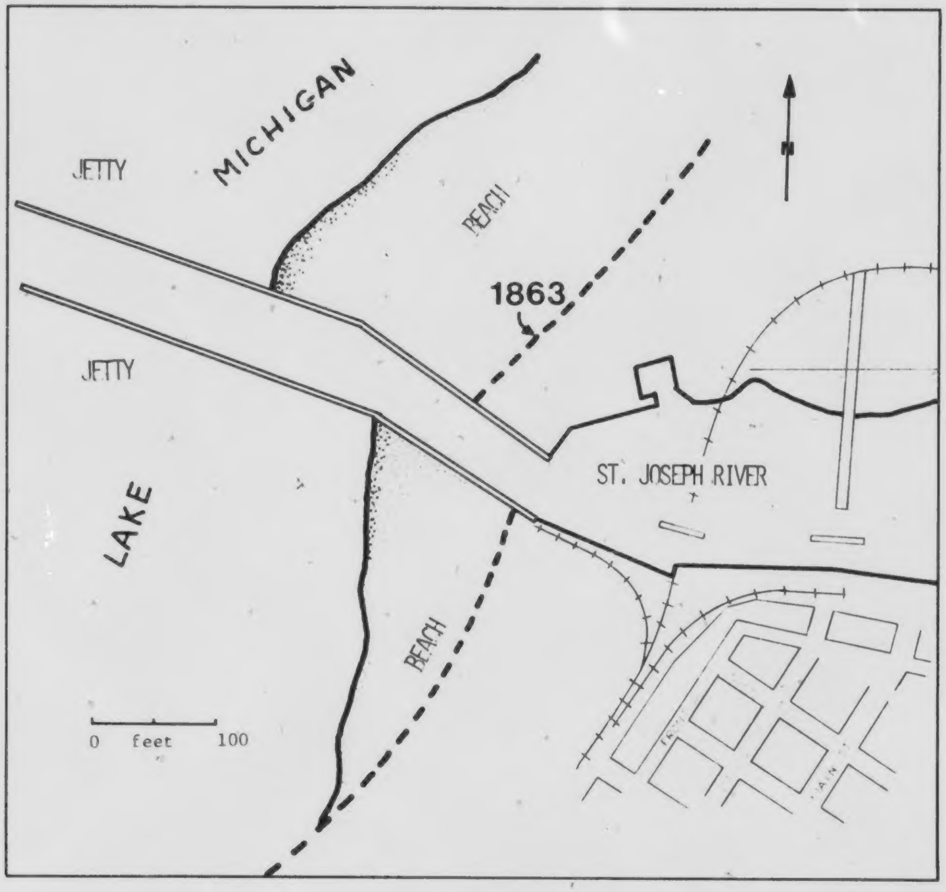


Figure 11. Beach accretion adjacent to jetties at mouth of St. Joseph River, 1863 to 1967. Bluff erosion is accelerated immediately to the south of this area to the Grand Mere Lakes (after Gare, Engineers, Inc., 1976).

and layers containing both compositions. These high bluffs have been undergoing severe shoreline erosion since 1969, and the stability of the Red Arrow Highway has been endangered and extensive private property losses have been sustained. An engineering study reveals a situation similar to that existing at the Indiana Dunes National Lakeshore.[10]

Erosion appears to result from storm wave activity crashing at the base of the bluff at high lake levels when beaches are extremely narrow. This erosion is compounded by the St. Joseph harbor jetties which intercept a southward littoral drift. Thus, deposition occurs north of the harbor and erosion is intensified southward of the structure (Figure 11). Also, the annual dredging of the harbor channel maintains an open trap for

MUCH OF THE LITTORAL DRIFT THAT DOES BYPASS THE HARBOR FROM NORTH TO SOUTH. THE BEACH JUST SOUTH OF THE HARBOR PROBABLY RESULTS FROM MINOR NORTHWARD LITTORAL DRIFTING WHICH EXISTS FROM TIME TO TIME.

THE SANDY BLUFFS ERODE MORE QUICKLY THAN THE CLAY BLUFFS, HOWEVER, GROUND WATER SATURATION OF THE CLAY MATERIALS CAUSES THESE UNITS TO COLLAPSE AND SLUMP WHEN UNDERCUT AT THEIR BASES. THE AVERAGE ANNUAL EROSION RATE IS ESTIMATED TO BE 2.14 FEET PER YEAR. ENGINEERING CONSULTANTS RECOMMEND BEACH NOURISHMENT AS THE MAJOR REMEDY; THEY ALSO SUGGEST THAT GROINS BE PLACED IN THOSE REACHES WHERE EROSION IS MOST SEVERE. HARBOR DREDGE IS SUGGESTED AS A POSSIBLE BEACH NOURISHMENT SOURCE; HOWEVER, THE POTENTIAL OF ENVIRONMENTAL CONTAMINATION FROM THESE SEDIMENTS MAY EXIST. THE COST OF SUCH A PROJECT ESTIMATED AT THE START OF THIS DECADE WAS BETWEEN FOUR AND SIX MILLION DOLLARS.

SHORELINE EROSION OF THE BLUFFS FROM WILMETTE TO WAUKEGAN, ILLINOIS

THE PORTION OF THE COAST FROM WILMETTE TO WAUKEGAN, ILLINOIS IS LINED WITH BLUFFS COMPOSED OF TILLS WITH SOME SAND, CLAY, AND SILT LENSES. THESE BLUFFS RISE FROM 30 FEET ABOVE THE LAKE NEAR WILMETTE TO NEARLY 100 FEET NEAR HIGHLAND PARK. THE BLUFF IS OVERSTEEPENED BY WAVE EROSION AT ITS BASE AND ABOUT 10 PERCENT OF THE BLUFFLINE IS CURRENTLY ERODING. THE EROSION PRODUCED BY THE WAVE ACTION UNDERCUTS THE CLIFF AT ITS BASE AND IS FOLLOWED BY SLUMPING OF THE OVERLYING CLIFF MATERIALS AND RECESSION LANDWARD OF THE TOP OF THE BLUFF. MOST OF THE REST OF THE BLUFFLINE IS PARTIALLY PROTECTED BY VEGETATION AND MAN-MADE STRUCTURES. THE SHORELINE FROM WAUKEGAN NORTH TO THE STATE LINE CONSISTS OF A STABILIZED BLUFF, AS A MILE-WIDE BEACH RIDGE COMPLEX SEPARATES THE BLUFF FROM THE LAKE'S EDGE.

EROSION HERE IS PRIMARILY THE RESULT OF THE CURRENTLY HIGH LAKE LEVEL. THE CHIEF EFFECT HAS BEEN THE SUBMERGENCE AND REMOVAL OF THE WIDE SAND BEACH, UNDERCUTTING OF THE TILL BLUFFS WHERE STORM WAVES CRASH AT THE BASE OF THE BLUFF, SLUMPING BY THE UPPER BLUFF, AND REMOVAL OF THE SLUMPED MATERIALS BY LONGSHORE AND OFFSHORE CURRENTS. THE PRIMARY USE OF THIS SHORELINE REACH IS LOW DENSITY RESIDENTIAL. CURRENT EROSION RATES RANGE AS HIGH AS FIVE FEET PER YEAR IN THE MOST ACTIVE EROSION AREAS.

WE HAVE ONLY RECENTLY COME TO REALIZE THAT SHORELINE EROSION CANNOT BE TOTALLY OR PERHAPS EVEN EXTENSIVELY BROUGHT UNDER CONTROL. INDEED THE NATIONAL PARK SERVICE RECENTLY ADOPTED A POLICY OF, WHEREVER POSSIBLE, TO MANAGE SHORELINES AS NATURAL FEATURES; AT TIMES ACTIVELY BEING ERODED AND AT OTHER TIMES ACTIVELY PROGRADING. THE NEED EXISTS TO FURTHER DEVELOP AND

IMPLEMENT POLICIES AND PROGRAMS WHICH REDUCE SHORELAND DAMAGE IN GENERAL, AND ONLY EXTENSIVELY MITIGATE EROSION IN THOSE SEVERELY IMPACTED AREAS WHERE THE COMMITMENT TO CURRENT LAND USES ARE IRRETRIEVABLE.

SEVERAL ALTERNATIVES ARE AVAILABLE. THESE WERE DELINEATED IN THE GREAT LAKES BASIN FRAMEWORK STUDY: APPENDIX 12, SHORE USE AND EROSION.[9] THEY ARE AS FOLLOWS:

1. FURTHER UTILIZE LAKE REGULATION TO REDUCE HIGH LEVELS,
2. BOTH PERMANENT AND TEMPORARY STRUCTURAL PROTECTION DEVICES,
3. REGULATORY ACTION TO AVOID OR MODIFY CONSTRUCTION IN NAVIGABLE WATERS THAT TENDS TO AGGREVATE EROSION,
4. REMEDIAL MEASURES TO MODIFY IMPROPERLY DESIGNED NAVIGATION WORKS AND TO REPAIR ACCUMULATED DAMAGE,
5. ZONING AND STRUCTURAL SET BACK REQUIREMENTS TO PRESENT FURTHER DEVELOPMENT ON VULNERABLE SHORELANDS,
6. ACQUISITION AND RELOCATION OF DEVELOPMENT FROM VULNERABLE SHORELANDS, AND
7. INSURANCE AGAINST OR REIMBURSEMENT FROM OTHER SOURCES FOR DAMAGE FROM EROSION AND FLOODING.

OBVIOUSLY, NO SINGLE ALTERNATIVE WILL BE SUFFICIENT. ONLY A COMBINATION OF ENGINEERING AND PUBLIC POLICY MEASURES CAN REDUCE THE PROBLEM OVER TIME. THE COASTAL ZONE MANAGEMENT PROGRAMS IN EACH OF THE FOUR STATES PROVIDE A DIRECT AVENUE FOR PROPER POLICY FORMATION AND THIS IS A HOPEFUL SIGN. HOWEVER, OUR KNOWLEDGE OF THE DETAILS OF SHORELINE PROCESSES IN LAKE MICHIGAN IS NOT YET ADEQUATE. MUCH FURTHER RESEARCH IS NECESSARY BEFORE BETTER ENGINEERING SOLUTIONS ARE DEVELOPED.

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RICHARD L. ROBBINS

RICHARD L. ROBBINS is Executive Director of the Lake Michigan Federation. His organization has long been active in Lake Michigan affairs, representing citizens before agencies, lobbying administrators and legislators, producing research usable by citizens and aiding in citizen participation. The Federation has run workshops, set up task forces, run three day institutes, published newspapers and tracked citizen suggestions through the administrative process.

Dick is a lawyer and an engineer. He has worked in government and taught law. He lives in Evanston, bicycles and swims a lot.

PUBLIC PARTICIPATION IN GREAT LAKES DECISIONS

THERE IS A STORY ABOUT AN ELECTED OFFICIAL WHO ONCE MADE A REZONING DECISION WITHOUT HOLDING A PUBLIC HEARING -- A HEARING THAT WAS REQUIRED BY LAW. WHEN ASKED ABOUT THIS HE LOOKED AT HIS QUESTIONER AS IF HE WERE A SUBVERSIVE AND SAID "WE DON'T NEED PUBLIC PARTICIPATION HERE, REMEMBER THIS IS A DEMOCRACY".

AND SO IT GOES.

AT PUBLIC HEARINGS CITIZENS TESTIFY LAST.

CITIZENS HAVE LITTLE TO SAY ABOUT MAJOR LAKE MICHIGAN DECISIONS UNTIL LONG AFTER THE PLANNERS AND THE OFFICIALS HAVE DONE THEIR WORK.

CITIZEN ADVISORY COMMITTEES SET UP BY AGENCIES ARE HOSTAGE TO THOSE AGENCIES, OFTEN MERE "COMPANY UNIONS".

CITIZEN INVOLVEMENT IS OFTEN DELEGATED TO THE PUBLIC AFFAIRS OFFICE WHICH TENDS TO SEE PARTICIPATION AS SO MUCH MARKETING OF A PRODUCT ALREADY DESIGNED.

YET IN THE LAKE MICHIGAN AREA EFFECTIVE CITIZEN PARTICIPATION IS NEEDED. THERE ARE HUNDREDS OF AGENCIES, LOCAL GOVERNMENTS, SPECIAL DISTRICTS, BOARDS AND COMMISSIONS WHOSE DECISIONS SERIOUSLY AFFECT THE LAKE. THEY MAKE PLANS, REGULATE, MONITOR, ENFORCE AND SPEND OR ALLOCATE FUNDS. BEYOND THESE PUBLIC AGENCIES ARE THE PRIVATE GROUPS - THE BUSINESSES, PROPERTY OWNERS, INDUSTRIES AND TRADE GROUPS WHOSE ACTIONS OFTEN AFFECT LAKE MICHIGAN EVEN MORE SUBSTANTIALLY.

CITIZENS HAVE WORKED TO MAKE THESE AGENCIES AND GROUPS MORE RESPONSIVE TO CITIZEN NEEDS. ORGANIZED IN GROUPS LIKE THE LAKE MICHIGAN FEDERATION, THE LAKE MICHIGAN INTER-LEAGUE GROUP OF THE LEAGUE OF WOMEN VOTERS, AND THE WEST MICHIGAN ENVIRONMENTAL ACTION COUNCIL, FOR EXAMPLE, THEY HAVE TRIED TO IMPROVE PARTICIPATION. AND SOME AGENCIES HAVE EXTENDED THEMSELVES AND CLEARED NEW GROUND FOR PARTICIPATION. THE JOB HAS NOT BEEN EASY, BUT EVERYONE HAS FELT THAT IT WAS NECESSARY. THIS MATERIAL WAS CREATED OUT OF THESE EXPERIENCES, AND OTHERS IN THE REGION, TO MAKE PRESENT CITIZEN PARTICIPATION MORE EFFECTIVE AND IMPROVE FUTURE CITIZEN PARTICIPATION.

WHO IS THE CITIZEN IN CITIZEN PARTICIPATION?

CITIZENS GENERALLY INVOLVED IN PARTICIPATION INCLUDE LOBBYISTS FOR MAJOR INTEREST GROUPS, ELECTED REPRESENTATIVES, RESIDENTS OF AREAS AFFECTED BY SOME ACTION, USERS OF THESE AREAS AND THOSE WITH SOME ECONOMIC, SOCIAL OR CIVIC CONCERN FOR AN AREA, PARTICULARLY FOR A RESOURCE OR SPECIAL OBJECTIVE.

FOR EXAMPLE, A PROGRAM TO PROTECT THE FISHERY FROM TOXIC SUBSTANCES COULD INVOLVE THE

MAKER OF THE SUBSTANCE, THE USER, THE TRANSPORTER, THE DISPOSER OF TOXIC WASTES, FISHERPERSONS, HARBOR OR PORT OFFICIALS, LOCAL HEALTH DEPARTMENTS, FISH CONSUMERS, BOAT SUPPLIERS, ENVIRONMENTALISTS, BIOLOGISTS, FISH SELLERS AND MANY OTHERS.

THOUGH CITIZEN PARTICIPATION AFFECTS THEM ALL, MANY OF THESE CITIZENS ALREADY HAVE ADEQUATE CHANNELS FOR COMMUNICATING THEIR VIEWS TO THE AGENCY. THEY USE WELL-PAID LOBBYISTS OR MAJOR TRADE ORGANIZATIONS; OR THEY HAVE A SUBSTANTIAL ECONOMIC INTEREST WHICH PROVIDES A CHANNEL. SINCE IMPROVEMENTS IN CITIZEN PARTICIPATION NEED TO BE AIMED AT OTHERS - IT IS THESE OTHERS WITH WHICH THIS MATERIAL IS CONCERNED.

GENERALLY, THEY INCLUDE:

1. Users of an area who are not well organized.
2. Residents of an area who are not well organized.
3. Citizens confronted with a remote agency or a well-established and powerful agency.
4. Citizens who are spread over a large area.
5. Citizens, each of which has only a relatively small interest in the issue.

IN THE LAKE MICHIGAN AREA CITIZENS WITH WHICH WE ARE CONCERNED OFTEN INCLUDE:

1. Residents, shoreland property owners, fisherpersons, swimmers, boaters and sailors.
2. Local government officials, port authorities, sewer and water districts (especially when state or federal agencies or large industries are planning action).
3. Local civic and environmental groups and their members.
4. Labor unions, small businessmen, small manufacturers, resort owners, local business leaders.

WHAT IS CITIZEN PARTICIPATION?

CITIZEN PARTICIPATION IS EFFECTIVE COMMUNICATION BETWEEN AN AGENCY (THE TERM AGENCY INCLUDES ANY PRIVATE OR PUBLIC GROUP ATTEMPTING TO AFFECT LAKE MICHIGAN) AND CITIZENS.

THERE ARE TWO MAIN ELEMENTS TO COMMUNICATION. FIRST, A MECHANISM IS NEEDED THAT ENCOURAGES AND PERMITS ACTUAL COMMUNICATION OF CITIZEN VIEWS TO AN AGENCY. THE MECHANISM MUST CONSIDER DIFFERENCES IN UNDERSTANDING OF TECHNICAL LANGUAGE, DIFFERENT TECHNIQUES OF COMMUNICATION AND NUMEROUS OTHER COMMUNICATION FACTORS. CITIZENS DO NOT ORDINARILY SPEAK THE LANGUAGE OF EXPERTS. OR CITIZENS MAY SPEAK TO POLICIES, NOT TECHNICAL DETAILS.

THE SECOND IMPORTANT ELEMENT CAN BEST BE CALLED RECEPTIVITY. IT IS THE AVAILABILITY OF A PROCESS WITH INHERANT POTENTIAL FOR CITIZEN OPTIONS OR VIEWS TO BE INCORPORATED INTO AN AGENCY PROGRAM--OR TO OTHERWISE BE ADOPTED AND USED. COMMUNICATION FAILS TO OCCUR WHERE TECHNICIANS HOLD A PUBLIC HEARING AND FAIL TO UNDERSTAND NON-TECHNICAL ADVICE SUCH AS CHOICES, VALUES OR POLICIES. WHERE AN AGENCY HOLDS A PUBLIC HEARING LONG AFTER MOST FUNDS ARE SPENT, SAY, IN EXAMINING ALTERNATIVE METHODS OF SAND MINING, LITTLE RECEPTIVITY EXISTS SINCE NOTHING CAN BE DONE TO UTILIZE CITIZEN IDEAS.

WHAT IS THE BASIS FOR CITIZEN PARTICIPATION?

THERE MUST BE RATIONALE FOR CITIZEN PARTICIPATION. RATIONALE GUIDES PARTICIPATION ACTIVITIES, REINFORCES CITIZENS TAKING PART BY MAKING THEIR ACTIVITY PART OF A GREATER

OBJECTIVE, AND ENCOURAGES MORE EFFECTIVE PARTICIPATION.

THERE ARE AT LEAST SEVEN BASIC REASONS FOR CITIZEN PARTICIPATION.

1. It is required by law or regulation. The U.S. Coastal Zone Management Act of 1972 requires such participation, as does the Clean Water Act of 1972.
2. A legislature has delegated discretionary authority to an agency. For example, an agency may have to develop rules to carry out a law that requires standards for levels of dissolved oxygen in water. The agency can make its own decisions. However, if the decisions are to be democratic and responsive to the public, participation is needed. The important factor here is that the agency is making policy about future uses of the water.
3. Citizens have facts about a situation often not readily available to an agency. A long-time fisherperson in an area may know a great deal about spawning areas that the Army Corps may need to know if dredging or filling is anticipated in the area.
4. A government program which distributes funds, or administers a permit process requires agencies to work with citizens. Participation can make that process meet agency needs and citizen constraints in the most efficient manner.
5. Citizens pay for government programs, planning for new programs, operation of existing programs, and the private costs of compliance with programs. Similarly citizens pay the health costs when pollution controls are not strict. Where a smaller group than the general public is primarily affected by agency action this rationale for participation is even stronger.
6. Citizen participation can enhance an agency's approach to regulation. Critical citizen review of a program or policy mobilizes people with abilities. This expands the expertise applied to problem solving. In addition, citizens can unearth facts which conceal assumptions and policies. For example, a fact that 5ppm PCB in fish is unhealthy involves a policy decision that the risk of 4ppm is acceptable.
7. Participation can also build a constituency for a program. Where legislative support is required, or the backing of public opinion needed, participation can help provide a knowledgeable citizenry capable of later supporting the program.

WHERE CITIZENS AND THE AGENCY ARE AWARE OF THESE REASONS WHICH SUPPORT PARTICIPATION, BOTH AGENCIES AND CITIZENS FEEL MORE POSITIVELY ABOUT THE ROLE OF PARTICIPATION IN PUBLIC DECISION-MAKING AND PARTICIPATION ITSELF IS STRONGLY ENHANCED.

BASIC RATIONALE OR REASONS FOR PARTICIPATION SHOULD BE CONSIDERED WHEN DESIGNING, OPERATING OR EVALUATING A CITIZEN PARTICIPATION PROGRAM.

BASIC RATIONALE OR REASONS FOR PARTICIPATION SHOULD BE CONSIDERED WHEN DESIGNING, OPERATING OR EVALUATING A CITIZEN PARTICIPATION PROGRAM.

THE TECHNIQUES OF CITIZEN PARTICIPATION

THERE ARE MANY WAYS TO CARRY OUT A CITIZEN PARTICIPATION PROGRAM. A COMMON TECHNIQUE IS TO HOLD A PUBLIC HEARING JUST BEFORE THE AGENCY MAKES A FINAL DECISION. ALTERNATIVELY SOME AGENCIES CONTEMPLATING MAJOR CHANGE INVOLVE THE PUBLIC FROM THE VERY BEGINNING. THE PUBLIC HELPS TO ISOLATE PROBLEMS, SET PRIORITIES, DEVELOP SOLUTIONS, DEVELOP PROGRAMS, DRAFT LEGISLATION OR RULES AND OVERSEE ADMINISTRATION.

IN BETWEEN THESE TWO EXTREMES ARE A BROAD VARIETY OF TECHNIQUES USED FOR PARTICIPATION. THIS SECTION OUTLINES A FEW OF THOSE TECHNIQUES--THE PUBLIC HEARING AND THE RELATED PUBLIC MEETING; THE TASK FORCE COMMITTEE OR CITIZEN ADVISORY GROUP; THE WORKSHOP, THE PUBLIC INFORMATION MATERIAL AND THE ACCOUNTABILITY TECHNIQUES USED TO IMPROVE THE RESPONSE OF AN AGENCY AND ITS STAFF TO WHAT THE PUBLIC SUGGESTS.

ONE POINT IS BASIC, THOUGH, TO ANY DISCUSSION OF CITIZEN PARTICIPATION TECHNIQUES. IT IS NOT THE AGENCY ALONE WHICH SELECTS THE TECHNIQUES. NOR NEED AN AGENCY ALONE ADMINISTER THE PARTICIPATION PROGRAMS. AT THE GREAT LAKES BASIN COMMISSION, FOR EXAMPLE, CITIZENS HELPED SELECT TECHNIQUES TO BE USED AND DESIGNED THE PROGRAM. IN ANOTHER CASE, LITIGATION BY A PUBLIC INTEREST GROUP RESULTED IN A FEDERAL AGENCY REQUIRING A STATE AGENCY TO INVOLVE THE PUBLIC IN A WASTEWATER MANAGEMENT PROGRAM.

CITIZENS HAVE A ROLE IN THE DESIGN, ADMINISTRATION AND EVALUATION OF CITIZEN PARTICIPATION PROGRAMS.

WHERE CITIZENS HAVE NOT FOUND PROGRAMS THAT SATISFIED THEIR NEEDS THEY HAVE PRESSURED FOR CHANGE, PERSUADED PUBLIC OFFICIALS TO ADD NEW PROGRAMS OR NEW FUNDING OR INITIATED THEIR OWN CITIZEN PARTICIPATION ACTIVITIES.

EVERY TECHNIQUE AND EVERY CITIZEN PARTICIPATION PROGRAM SELECTED BY AN AGENCY SHOULD MEET THE FOLLOWING CRITERIA:

1. The techniques should meet statutory requirements
2. They should be aimed at a desired constituency--boaters if there are to be new harbors, environmentalists if those harbors impact water quality, people concerned with parks if the harbors affect use of nearby parkland.
3. The techniques should recognize that all citizens are not equally skilled in communication. Different methods should be provided for those who are adept at speaking, at writing, at working in small groups, or in reading and making responses.
4. The techniques should recognize the different types and levels of information to be communicated. A forum is different if residents are to be heard about objections to a new land use plan than if lobbyists for a national group are to testify. If a biologist is to present information he will need more time, the opportunity to present written and audio-visual materials and audio-visual equipment facilities.
5. The technique should recognize the need for convenience and the need to encourage participation. Hearings should be held at hours that conform closely to the hours available for volunteer efforts. Where busy people are to participate, meetings and hearings might have prescheduled testimony.
6. The techniques should recognize differences in language and comprehension. Technical experts who sit on hearing panels, or who monitor task force meetings may not understand lay persons. And lay persons may not understand technical presentations or inquiries. Interpreters may be necessary.
7. A technique should recognize different degrees of commitment, concern or interest. Some people may be willing to spend one day a week on participation, others have one hour a week, others ten minutes in total.

8. The techniques and the participation program should be built into the agency decision-making process, or the process designed around the participation to allow participation to have an effect on that decision making. A committee should not be convened to analyze a coastal zone program when 90% of the funds for the planning have been committed. Nor should a new proposal for an erosion control system be brought before the public when only fifteen days remain before necessary construction is to begin.

9. The techniques must be not only part of the decision-making process but should include methods to insure consideration of citizen views. Also, an accountability process should trace citizen views through the agency to determine where and when they were used or not used.

10. The techniques must be attuned to the effect of participation. Some techniques such as "advisory" committees are better suited for an "advisory" role. Other techniques such as formal public hearings are used where citizen information must be considered unless the agency presents evidence to the contrary.

11. The technique must be used in the most effective manner. A workshop to discuss policy issues in phosphorus pollution may not be very helpful unless citizens have been fully briefed on the factual issues, current research findings, existing pollutant loads and effects. Needed technical assistance, public information and data must be available to supplement the technique.

FOR THE CITIZEN THERE IS ANOTHER SET OF REQUIREMENTS FOR PUBLIC PARTICIPATION. FOR EVERY PARTICIPATION ACTIVITY CITIZENS SHOULD REVIEW THE FOLLOWING CRITERIA:

1. Am I fully aware of the location in the decision process of the participation program? Is it at the end of the process? Will there be more reviews: Is more data to be made available?

2. Am I aware of the exact materials to be discussed and the issue under consideration?

3. Am I fully briefed on the technical data, the facts that I know? Have I brought photos, contacted others with special information and examined the area or situation as closely as I can?

4. Have I selected the technique and the time commitment which most closely reflects my ability and interest? Will I go to a public hearing, write a short note, or wait to be polled by telephone?

5. Have I informed the agency of my concern and interest in participation?

6. Have I recognized potential communication barriers with the agency and its staff? Will I ask for some interpretation, bring along a technical expert, or ask the agency to listen more closely?

7. Have I prepared the presentation in the most effective possible form? Will I bring along written testimony to supplement my verbal testimony? Do I need a press release? Have I contacted the press? Do I have a list of issues to bring to the workshop? Should I bring photos?

8. Am I prepared to follow up afterwards to insure that my information was considered? Will I call the agency? Will I ask them to track my testimony to the proper persons making decisions?

9. Have I notified other citizens and coordinated my presentations with them?

10. If the agency doesn't have an adequate program of public participation that meets my needs, have I asked them to improve their program and suggested alternative methods?

THE TECHNIQUES THEMSELVES

THERE ARE AT LEAST FOUR TECHNIQUES WHICH ARE WIDELY USED IN THE LAKE MICHIGAN AREA BY

REGIONAL PLANNING AGENCIES, LOCAL GOVERNMENTS, FEDERAL AGENCIES AND STATE GOVERNMENTS. THEY ARE:

1. The Public Hearing
2. Citizens Newspapers and Information Sheets
3. Citizen Advisory Committees and Task Forces
4. Workshops

IN ADDITION TO THE FOUR TECHNIQUES THERE ARE TWO OTHER COMPONENTS OF PARTICIPATION WHICH ARE IMPORTANT. THEY ARE:

1. Use of local coordinators to assist in local arrangements and local participation
2. Use of a system of accountability to insure that all citizen participation is considered by the agency

THE REMAINING SECTIONS OF THIS MATERIAL DESCRIBE THESE TECHNIQUES AND COMPONENTS. A BIBLIOGRAPHY CONTAINS A LISTING OF FURTHER ARTICLES ON CITIZEN PARTICIPATION.

PUBLIC HEARING

THE PUBLIC HEARING IS AN IMPORTANT PART OF PUBLIC PARTICIPATION. IN FACT, THE PUBLIC HEARING IS THE WORKHORSE OF PARTICIPATION BY BEING THE EXCLUSIVE MEANS OF PARTICIPATION. UNFORTUNATELY, THE HEARING HAS NOT BEEN THE WELL-DEVELOPED FORUM THAT IT COULD BE.

WHAT IS WRONG WITH THE HEARING?

1. As the exclusive means of participation it fails to give an opportunity to those who cannot or do not speak well.
2. The hearing is often an adversary process. The agency defends its position. Citizens are discouraged from participation when faced with heavy technical arguments in return.
3. Presentations are not geared to the capability or concerns of the citizens. Very often a maximum time for testimony is set and citizens with a great deal of information have inadequate time for presentations.
4. Presentations are often unscheduled. Those citizens with other obligations--i.e., the busy expert or the businessperson--cannot wait through four hours of testimony by officials and other citizens.
5. There is inadequate opportunity to explore citizen's suggestions. Very often some interpretative questioning of those who testify can elicit the basic assumptions or other facts of importance. Rarely is that questioning done. The hearing is generally not a two-way discussion.
6. Timing and location of hearings is very often not well related to citizen ability to appear, or tends to discriminate against certain classes of citizens.
7. Notices of the hearing are often not timely received. They generally contain little information about the issues or concerns. Notices are not worded so as to develop concerns where they might otherwise be merely latent.
8. Citizens are often inadequately prepared for hearings. Especially when water quality policies or facts are involved, citizens often need background briefings and technical assistance in order to cope with the issues. Failure to provide this assistance often results in citizens not appearing or testimony not being helpful to an agency.

9. Hearings generally are scheduled at the end of a process rather than the beginning. Decisions are usually made by that time.

FROM THE ABOVE CRITICISMS, IT IS CLEAR THAT A PUBLIC HEARING IS NOT LIKELY TO BE A FRUITFUL PLACE FOR AN AGENCY TO RECEIVE INFORMATION FROM THE PUBLIC. THAT MEANS OTHER TYPES OF PARTICIPATION ARE NECESSARY AND SIGNIFICANT CHANGES NEEDED BEFORE HEARINGS BECOME MORE USEFUL.

THIS LEADS TO AN EXAMINATION OF THE PUBLIC HEARING. THERE ARE TWO KINDS OF HEARINGS: FORMAL AND INFORMAL HEARINGS. A *FORMAL HEARING* IS ONE THAT COULD IN SOME PROGRAMS BE THE ONLY ONE CALLED "HEARING". IT IS A *LEGALLY REQUIRED* HEARING. THE RULES THAT GOVERN THE HEARING ARE QUITE EXPLICIT. VERY OFTEN NOTICE MUST BE GIVEN IN PARTICULAR NEWSPAPERS FOR A CERTAIN PERIOD IN ADVANCE -- USUALLY 30 DAYS. CITIZENS MUST REGISTER AT THE HEARING. THEY WILL OFTEN FIRST HEAR A BRIEF PRESENTATION ON THE PROGRAM. THEN PERSONS WISHING TO TESTIFY WILL BE GIVEN A CHANCE TO SPEAK. A HEARING OFFICER RUNS THE HEARING AND TAKES TESTIMONY IN A FORMAL MANNER. RARELY IS ANYONE PERMITTED TO CROSS EXAMINE ANOTHER PERSON OR EVEN A PERSON FROM THE AGENCY. USUALLY NO QUESTIONS CAN BE ASKED THAT WILL BE ANSWERED AT THE HEARING ITSELF.

A COURT REPORTER TRANSCRIBES WHAT IS SAID AT THE HEARING. PEOPLE WHO TESTIFY MAY ALSO SUBMIT WRITTEN STATEMENTS. GENERALLY THE "RECORD" IS LEFT OPEN FOR A PERIOD SUBSEQUENT TO THE HEARING SO THAT THOSE WHO TESTIFIED AND OTHERS CAN WRITE THEIR TESTIMONY TO THE AGENCY.

THIS FORMAL HEARING MUST MEET ALL STATUTORY AND REGULATORY REQUIREMENTS IN ORDER TO BE OFFICIAL. VERY OFTEN FAILURE TO MEET THE REQUIREMENTS CAN RESULT IN A REQUEST GRANTED TO HOLD A NEW HEARING AND IN A DELAY IN WHATEVER ACTION THE HEARING PRECEDED.

A SECOND TYPE OF HEARING IS OFTEN CALLED A "PUBLIC HEARING" OR *INFORMAL HEARING*. IN THIS HEARING THE PROCEDURE MAY BE EITHER INFORMAL OR FORMAL DEPENDING UPON THE APPROACH OF THE AGENCY. FEW LEGAL REQUIREMENTS GUIDE THIS TYPE OF HEARING. THE HEARING CAN BE A DIALOGUE BETWEEN AGENCY STAFF AND CITIZENS, OR A HEARING EXAMINER MIGHT PROBE MORE DEEPLY INTO THE SUGGESTIONS OF CITIZENS.

SOME HEARINGS RESEMBLE WORKSHOPS. THE SECTION ON WORKSHOPS IN THIS MATERIAL DESCRIBES A HEARING CONDUCTED BY AN EXAMINER WHO PROBES SUGGESTIONS TO FIND THE UNDERLYING REASONS FOR POSITIONS.

IN ORDER TO IMPROVE CITIZEN SUGGESTIONS AND MAKE THE PROCEEDINGS MORE EFFECTIVE, HEARINGS CAN ALSO BE PRECEDED BY A TECHNICAL ASSISTANCE TYPE OF WORKSHOP. THIS WORKSHOP ALSO IS DESCRIBED IN THESE MATERIALS. THE BASIC WORKSHOP UTILIZES TECHNICAL EXPERTS WHO ASSIST CITIZENS TO DEVELOP THEIR CONCERNS AND RELATES THOSE CONCERNS TO READING MATERIALS OR REPORTS PREPARED IN ADVANCE OF A HEARING.

CITIZENS WHO TAKE PART IN HEARINGS SHOULD INSIST THAT THE AGENCY REPORT BACK TO CITIZENS ON WHAT WAS DONE WITH SUGGESTIONS MADE AT THE HEARINGS. CITIZENS SHOULD INSIST ON A REGULAR INTERNAL AGENCY PROCESS TO ROUTE AND CONSIDER SUGGESTIONS IN ADDITION TO THE REPORTING SYSTEMS.

IN MANY CASES, CITIZENS SHOULD ALSO REQUEST THAT TIMES FOR TESTIMONY BE SCHEDULED IN ADVANCE OF THE HEARING SO THAT BUSY CITIZENS CAN TESTIFY AND LEAVE. A NUMBER OF AGENCIES HAVE SUCCESSFULLY USED THE SCHEDULING TECHNIQUE AND INTEGRATED IT WITH A BRIEFING METHOD. THE BRIEFING IS DONE ON VIDEO TAPE OR IN A CONTINUOUS SLIDE SHOW AND GOES ON THROUGHOUT THE HEARING PERIOD. THUS, A CITIZEN WHO IS SCHEDULED TO TESTIFY AT 3 P.M. NEED NOT BE THERE FOR THE BRIEFING AT 9 A.M.

THE PUBLIC HEARING, WHETHER IT IS THE INFORMAL MEETING OR THE LEGALLY REQUIRED HEARING, IS A USEFUL METHOD FOR OBTAINING THE SUGGESTIONS OF CITIZENS WHO:

1. Have only a limited interest in the subject
2. Can testify without sustained technical briefing if the briefing is not offered
3. Can verbally express themselves
4. Can adequately express the underlying facts and assumptions where the hearing format does not allow for interpretative questions.

MANY PUBLIC AGENCIES PRODUCE PUBLICATIONS THAT ARE WIDELY DISTRIBUTED TO CITIZENS. IN THE GREAT LAKES AREA THESE INCLUDE ENVIRONMENT MIDWEST AND PUBLIC PARTICIPATION PRINTOUT, (U.S. EPA REGION FIVE); GREAT LAKES FOCUS (INTERNATIONAL JOINT COMMISSION) AND GREAT LAKES COMMUNICATOR (GREAT LAKES BASIN COMMISSION). MOST STATE COASTAL PROGRAMS HAVE THEIR OWN PUBLICATION. MANY STATE POLLUTION CONTROL AGENCIES ALSO HAVE A PUBLICATION. WITHIN THESE MYRIAD OF PUBLICATIONS THERE ARE OFTEN ARTICLES OF SUBSTANTIAL MERIT WHICH ARE EXTREMELY HELPFUL TO CITIZENS.

THE PUBLICATIONS GENERALLY AIM AT MORE THAN ONE OBJECTIVE. MANY PUBLICATIONS MUST NOT ONLY SERVE AS COMMUNICATION TO THE PUBLIC, BUT ALSO TO EXTOLL THE AGENCY'S ACCOMPLISHMENTS, PROVIDE TECHNICAL INFORMATION AND HELP THOSE TECHNICAL EXPERTS IN OTHER AGENCIES WHO ARE WORKING CLOSELY WITH THE PUBLISHING AGENCY.

MEETING ALL THESE GOALS HAS CERTAIN COSTS. IN SOME CASES, CITIZENS BECOME UNINTERESTED IN THE FINAL PUBLICATION. EFFORTS CAN BECOME TOO DIFFUSE AND RELATED TO SO MANY ISSUES THAT "FOCUS" IS WEAK. LANGUAGE USED MUST BE CITIZEN LANGUAGE TO INTEREST CITIZENS--THE RECENTLY CONCERNED AS WELL AS THOSE LONG CONCERNED AND MASTERS OF TECHNICAL JARGON. YET, JARGON OFTEN PERMEATES THE PUBLICATIONS AND MUCH OF THE INFORMATION IS FOR THE TECHNICALLY ADEPT ONLY.

WHERE THESE CITIZEN PUBLICATIONS ARE MEANT TO IMPROVE THE PARTICIPATION OF CITIZENS, THEY SHOULD:

1. Use clear, readable material.
2. Edit articles to encourage reader interest and include articles which are receptive to the reader and informal.
3. Provide basic information. In coastal programs this would mean articles on how erosion is caused, or what fish stocking means and how it is affected by coastal uses.
4. Integrate materials with a citizen participation program. Articles could relate to planned public hearings, or to the work of task forces. They should naturally feed people into task forces, workshops and hearings.
5. Avoid press release-type writing, limit promotion of the agency itself and use a more neutral stance.
6. Focus on the issues and problems, not the agency or the program.

MANY FORMS OF NEWSPAPER CAN BE USED TO MEET THESE GOALS. A FOUR OR EIGHT PAGE TABLOID IS READABLE AND SUITED TO THE MESSAGE CONVEYED. THIS TYPE OF NEWSPAPER HAS BEEN WRITTEN FOR THE LAKE MICHIGAN FEDERATION, THE INTERNATIONAL JOINT COMMISSION'S UPPER LAKES REFERENCE GROUP, THE ILLINOIS ENERGY OFFICE CONSERVATION PROGRAM, AND THE COASTAL ZONE PROGRAM IN ILLINOIS.

IN FOUR OF THESE NEWSPAPERS THE NEWSPAPER PUBLICATION WAS CONTRACTED OUT TO A CITIZEN PUBLIC INTEREST GROUP. THIS PROCEDURE OF CONTRACTING OUT SEEMS TO HAVE SOME FAVORABLE EFFECTS.

EVEN THOUGH THE AGENCY GENERALLY SUPERVISES FINAL COPY TO CORRECT ERRORS AND TO INSURE PROFESSIONAL PRESENTATION, THE NEWSPAPER IS NOT SEEN AS EMANATING FROM THE AGENCY AND, IN FACT, DOES NOT. THE INDEPENDENT SOURCE GIVES THE PAPER A MORE NEUTRAL PRESENTATION FORM. THIS FITS IN WELL WITH THE APPROACH THAT THE NEWSPAPER IS ABOUT THE ISSUES, NOT THE AGENCY.

USING A CONTRACTOR ALSO HELPS TO INSURE THAT AGENCY PUBLICITY ABOUT ITS ACCOMPLISHMENTS IS MINIMIZED AND EDUCATION TAKES PLACE. MANY PUBLICATIONS ARE EDITED BY THE SAME PERSON THAT ISSUES PROMOTIONAL PRESS RELEASES. A CONTRACT TO AN OUTSIDE GROUP CAN ALSO INSURE THE USE OF THE BEST QUALITY WRITERS WHERE AN AGENCY DOES NOT HAVE SUCH A STAFF OR WHERE THE PUBLICATION STAFF IS A TECHNICAL STAFF AND USES TECHNICAL JARGON NOT SUITED TO CITIZEN INFORMATION.

THE INDEPENDENCE OF MOST CONTRACTORS (ESPECIALLY INTEREST GROUPS WITH A SIMILAR PROBLEM FOCUS), THOUGH SOMEWHAT MOLLIFIED BY THE CONTRACTUAL RELATIONSHIP, IS UNDOUBTEDLY STRONGER THAN THE INDEPENDENCE OF AN EDITORIAL OR PRESS DEPARTMENT OR ANY OF THE USUAL CONSULTING FIRMS.

INTEREST GROUPS, TOO, ARE OFTEN CLOSER TO THE PUBLIC AND HAVE EXPERTISE IN BRIDGING THE GAP BETWEEN TECHNICAL AGENCY ACTIVITIES AND CITIZEN INTERESTS. HOWEVER, EDITING BY AN OUTSIDE INTEREST GROUP COULD IMPAIR THAT GROUP'S ROLE IN ADVOCACY AGAINST THE AGENCY AND UPSET THE PUBLIC PERCEPTION OF THE GROUP'S INDEPENDENCE.

The newspaper should encourage citizens to write to the newspaper and should publish acceptable letters; provide an easy and casual layout that does not look technically overwhelming; and be of a size small enough to be attractive.

A newspaper is of little use if it is not distributed broadly. A tough problem is to get the paper beyond the list of those already educated about the problems or already prone to make comments to a new audience of the general, but concerned public.

An agency could use mailing lists from universities, news offices, interest groups and civic groups. Copies could be distributed where people bought goods that related to use of the resource. (For coastal zone management this meant distribution in sporting goods, sailing and boating equipment stores in addition to other locations.) An insert in a local daily is effective if there are not too many materials competing for reader attention. Newspapers should also be placed in key locations in communities or areas affected by the problems. Newspapers could be distributed in bank lobbies, in libraries, at mass transit locations, and at all agency hearings and meetings held in these areas.

Costs for publishing these four to eight page tabloids which use 20 to 40 pages of copy are especially low. In 1977, an eight page tabloid, with an additional color on four of the pages and a total of 30,000 copies was printed for under $1,000. Staff time for writing costs about $1,000 as well.

Many citizens have an interest in a program which extends over a period of time. Or they have a desire to learn more about a program from the staff and then to discuss their concerns with the staff. Others have significant technical and factual assistance that cannot be provided in the hearing format.

Some public agencies need to test their assumptions and program designs with the various constituent groups who must provide legislative support, or who must live with the program. They need to work with a more stable group of people.

The Advisory Committee and the Task Force are one means to satisfy these needs.

The Advisory Committee, according to general usage in the Great Lakes area, is a group appointed by the agency. It is usually representative of the constituencies concerned with a program, meets once every one to three months and reviews the program and makes suggestions. Generally, the agency provides leadership to an advisory committee and the staff is available for technical consultation during and between meetings.

The Task Force operates in a similar manner. Except that generally the Task Force is not selected by the agency, but any citizen who wants to join can.

Task forces were widely used in the first two years of the development of the Illinois Coastal Zone Management program. In the third year, they were merged into an appointed Advisory Committee.

ADVISORY COMMITTEES EXIST FOR THE MICHIGAN NATURAL RESOURCES COMMISSION, THE WISCONSIN COASTAL ZONE PROGRAM AND THE GREAT LAKES BASIN COMMISSION. MANY OTHER AGENCIES AND PROGRAMS HAVE ADVISORY COMMITTEES AS WELL.

IT IS IMPORTANT TO DISTINGUISH THE DIFFERENT TYPES OF ADVISORY COMMITTEES AND TASK FORCES. SOME TASK FORCES OR ADVISORY COMMITTEES MAY BE ADVISORY TO THE AGENCY. OTHERS MAY ADVISE ONLY A SPECIFIC PROGRAM WITHIN AN AGENCY. STILL OTHERS MAY ADVISE ON ONLY ONE ASPECT OF A PROGRAM, A SINGLE ISSUE, SUCH AS THE EROSION ASPECTS OF COASTAL ZONE MANAGEMENT. SOME MAY HAVE "REPRESENTATIVES" OF CONSTITUENT GROUPS -- THE STEELWORKERS UNION, THE WISCONSIN MANUFACTURER'S ASSOCIATION, OR THE KOHLER COMPANY; OTHERS MAY HAVE MEMBERS WHO ARE MERELY CITIZENS WHO HAPPENED TO HAVE DIFFERENT EXPERIENCES AND DIFFERENT PERSPECTIVES ON A PARTICULAR AGENCY, PROGRAM OR ISSUE.

SOME OF THESE TASK FORCES OR ADVISORY COMMITTEES MAY OPERATE BY CONCENSUS -- VIRTUALLY 100% AGREEMENT. OTHERS OPERATE THROUGH MAJORITY VOTE. STILL OTHERS MAY TAKE NO POSITION AT ALL AS A GROUP, MERELY SERVING AS A CHANNEL FOR VARIOUS VIEWS TAKEN BY THE MEMBERS.

THE TWO GROUPS MAY ALSO HAVE A ROLE VIS-A-VIS THE GENERAL PUBLIC. SOME ARE USED TO ORGANIZE THE PUBLIC. OTHERS ARE USED TO GATHER INFORMATION FROM THE PUBLIC. STILL OTHERS MAY APPEAR ONLY AT PUBLIC HEARINGS TO GIVE THE VIEWS OF THE ADVISORY COMMITTEE OR TASK FORCE AND TO PERSUADE THE PUBLIC. SOME OF THE GROUPS HELP DESIGN OTHER PUBLIC PARTICIPATION PROGRAMS SUCH AS HEARINGS, POLLS AND WORKSHOPS. IN SOME IT IS THE SOLE PURPOSE--TO PROVIDE A PROCESS FOR LINKAGE WITH A LARGER PUBLIC.

ADVISORY COMMITTEES--ADVISORY COMMITTEES SUFFER FROM CERTAIN DEFECTS. OF NECESSITY THEY ARE SELECTED. THIS MEANS THAT MANY INTERESTED PERSONS ARE EXCLUDED. THE BASIS FOR SELECTION IS OFTEN NOT CLEAR NOR IS THERE ANY CLEAR AND ACCEPTABLE PROCESS FOR CARRYING OUT SUCH A SELECTION. SOONER OR LATER SOME CITIZEN IS GOING TO BE EXCLUDED AND SERIOUSLY CONTEST THE VALIDITY OF THE PROCESS -- ESPECIALLY WHEN FUNDS ARE EXPENDED BY OR ON BEHALF OF ADVISORY COMMITTEE MEMBERS AND AN AGENCY IS SEEN AS SELECTIVE ABOUT WHICH VIEWS ARE HEARD.

IMAGINE THE PROBLEM AS AN AGENCY HEAD SELECTING SUCH A COMMITTEE FROM HUNDREDS OF GROUPS CONCERNED OR POTENTIALLY CONCERNED WITH COASTAL ZONE ISSUES. THE LIST MERELY BEGINS WITH FISHERMEN, ICE FISHERMEN, CIVIC GROUPS, ENVIRONMENTAL GROUPS (PROBABLY THREE DOZEN OF THESE), SAILORS, YACHT CLUBS, HOMEOWNERS ASSOCIATIONS, MINORITY GROUPS, THE POOR, BICYCLISTS AND AD INFINATUM. THE CHANCES OF DEVELOPING ANTAGONISM AMONG THE EXCLUDED ARE VERY HIGH. AND THESE EXCLUDED GROUPS OR INDIVIDUALS CAN BECOME OPPONENTS OF A PROGRAM.

EXPERIENCE SHOWS THAT ADVISORY COMMITTEE MEMBERS ALSO BECOME HIGHLY ENTRENCHED IN THEIR POSITIONS. QUITE OFTEN THEY NEED NOT PRODUCE NOR ASSIST IN THE PROGRAM DEVELOPMENT TO KEEP THEIR POSITIONS. THEY BLOCK OTHERS FROM PARTICIPATION AND MAY DELIBERATELY ACCEPT APPOINTMENTS TO DO SO.

ADVISORY COMMITTEES ALSO BECOME CO-OPTED BY AGENCIES. MORE THAN ONCE WE HAVE FOUND MEMBERS DEFENDING THE AGENCY AND THE COMMITTEE OUT OF PROPRIETARY, NOT SUBSTANTIVE MOTIVE. AND AS AN OUTSIDER TO SOME COMMITTEES WE HAVE SEEN THEM OFTEN AS HIGHLY PROTECTIVE OF THE AGENCY. BUT AN EXTREMELY SERIOUS PROBLEM IS THAT THE COMMITTEE BECOMES JEALOUS OF ITS ROLE AND ACTS AS IF IT WERE THE SOLE CITIZEN INPUT. THE COMMITTEE BECOMES AN ALLY OF THE AGENCY WHEN OUTSIDERS CRITIQUE ACTIVITIES.

ANOTHER PROBLEM OCCURS WHEN AGENCIES BEGIN TO RELY WHOLLY ON THE CITIZENS ADVISORY COMMITTEE. THEY FORGET ABOUT OTHER BASES FOR CITIZEN PARTICIPATION SUCH AS DEVELOPING A COMMUNITY OF SUPPORT FOR THE PROGRAM AND RECEIVING FACTS FROM PERSONS RESIDENT IN THE AREA. SINCE THE COMMITTEE CANNOT REPRESENT ALL AREAS, OR ALL INTERESTS, OR ALL CITIZEN EXPERTISE, PARTICIPATION IS NEEDED FROM OTHERS.

RARELY DO MEMBERS CARRY A BROAD MANDATE FROM A CONSTITUENCY; WHEN THEY DO, THE OPERATION OF THE COMMITTEE BECOMES CUMBERSOME AS MEMBERS RETURN TO GROUPS TO GET APPROVAL OF THEIR ACTION.

ADVISORY COMMITTEES, TOO, BEGIN ACTING LIKE LITTLE LEGISLATURES. YET THEY HAVE NO PLENARY POWER. TRADEOFFS MADE WITHIN THE ADVISORY GROUP ARE RARELY BINDING AGAINST MEMBERS OR MEMBER GROUPS. THE FISHERMAN WHO GIVES UP SOME WATER QUALITY IN AN AREA FOR SOME OTHER BENEFIT (SUCH AS A NEW INDUSTRY OR PROTECTION OF ANOTHER SPAWNING AREA) CANNOT GUARANTEE FISHERMEN SUPPORT OF SUBSEQUENT ACTION BY THE AGENCY. NOR CAN HIS ADVERSARIES GUARANTEE THAT THE TRADEOFF FOR INDUSTRY WILL BE RESPECTED AND THAT THE FISHERMEN WILL NOT SUFFER FURTHER INCURSIONS ON THE VALUED WATER QUALITY PROTECTED IN THE TRADEOFF. YET THESE TYPES OF TRADEOFFS DO OCCUR.

IF THESE MATTERS WERE NOT SO SERIOUS AND IF THE POTENTIAL DEFECTS DID NOT TEND TO SEVERELY UNDERCUT THE VALIDITY OF SUCH CITIZEN PARTICIPATION, WE COULD CONTINUE TO CONCENTRATE ON USE OF THE ADVISORY COMMITTEE. HOWEVER, UNTIL A "GENERAL THEORY" OF ADVISORY COMMITTEES IS DEVELOPED -- ONE THAT IS CONSISTENT WITH DEMOCRATIC PRINCIPLES, WITH THE FUNDAMENTALS OF CITIZEN PARTICIPATION AND WITH EFFECTIVE DEVELOPMENT OF GOVERNMENT PROGRAMS, OTHER MEANS MUST BE TRIED AS WELL. THESE MEANS MUST GIVE CITIZENS OPPORTUNITIES FOR LONG TERM INVOLVEMENT IN GOVERNMENT PROGRAM DEVELOPMENT WITHOUT THE DANGERS OF THE COMMITTEE. THE CITIZEN TASK FORCE IS ONE OF THESE METHODS.

MUCH OF THE MATERIAL PRESENTED ON OPERATION OF TASK-FORCES IS ALSO APPLICABLE TO THE ADVISORY COMMITTEE.

TASK FORCE -- A CITIZEN TASK FORCE IS A GROUP OF VOLUNTEER CITIZENS WHO WORK TOGETHER OVER A PERIOD OF MONTHS OR YEARS AS A COMMITTEE. THE TASK FORCE IS MEANT TO BE OPEN TO ALL CITIZENS. ANY CITIZEN CAN JOIN AND CAN WORK WITH THE TASK FORCE SO LONG AS THE CONTRIBUTION IS VALUABLE. THIS ALLOWS ALL INTEREST GROUPS AND ALL INDIVIDUALS TO DEVELOP A RELATION-

372

ship with the agency and agency staff, and reduces elitism present in other methods. The task force is the more intensive version of the workshop and the open form of the Advisory Committee.

Task forces usually have appointed heads. They can be appointed by the agency -- to insure that administration is adequate and leadership effective. Or leadership could be appointed by the task force itself. However, the fluid membership of most task forces makes self-selection of a chair very risky.

Task forces are generally involved in a single subject area. In coastal management in Illinois where there was two years experience in use of the task force the topics were water quality, erosion, land use, industry and ports, and recreation. Or a task force could be centered on a single geographic area covering a multitude of problems.

A task force could focus on a particular program area such as "nonpoint source pollution" or "areas of particular concern". The focus should be extremely responsive to citizen needs, making it easy for them to relate to the issues and to the program. (The breakout by "program area" is often too obtuse to attract many citizen participants.)

Task forces are asked to bring information to the agency so as to affect the activity. They also review program activities. The task force is a long-term generator of facts, issues, critiques, program alternatives and other inputs to the government.

Task forces need to interact closely with the agency. Communication links need to be tight and well developed. Agency staff and task force members need to develop a respect for each other and an understanding of the problems faced by both groups.

The task force is not a representative of anybody, including the citizens as a whole or any interest group. Its suggestions are not binding on the agency. Nor is consensus or agreement necessary for suggestions to flow to the agency. The persuasiveness of presentation is as effective as the force's facts and arguments. Task forces, themselves, may survey the public for information, run other citizen participation activity or help design agency citizen participation.

Task force operation involves selection of leadership, development of participation methods, guidance in activities, and interaction with staff.

Selection of leadership is critical to the task force. Since leaders have no particular models from which to gain an understanding of the role, it is important that the leaders be self starting, aggressive and well-organized. Much depends on finding the right kind of people who have some technical background in the area, or an ability and willingness to learn, some organizational capacity and a bent for leadership. Where such persons are available the task force effort has been largely successful.

Leadership can be found in existing committees, in civic groups, interest groups, those

AFFECTED BY AGENCY ACTIVITIES AND ON RELATED UNIVERSITY FACULTY.

MEMBERSHIP SHOULD BE FOUND THROUGH MAIL AND PERSONAL SOLICITING OF THOSE WHO ATTEND HEARINGS AND ASK QUESTIONS OF THE AGENCIES, FROM INTEREST GROUPS, LANDOWNERS AND USERS OF AFFECTED AREAS. CONTINUAL MEMBERSHIP SOLICITATION IS USUALLY NECESSARY TO PROVIDE NEEDED REPLACEMENTS FOR MEMBERS OF THE TASK FORCE.

AN IMPORTANT PROBLEM TO THE TASK FORCE IS THE ORIENTATION OF NEW MEMBERS. CRITICAL PROBLEMS OCCUR WHEN NEW MEMBERS HAVE TO LEARN ABOUT THE NATURE OF THE PROGRAM AND THE NATURE OF THE PROBLEMS THAT THE TASK FORCE FACED DURING OPERATION OF THE GROUP. SEVERE IMPEDIMENTS CAN RESULT.

TO REDUCE THE PROBLEM, AN ORIENTATION SESSION, GIVEN ON A MONTHLY BASIS, COULD BE USED TO BRIEF NEW PARTICIPANTS IN THE PROGRAM AND THE ACTIONS OF A TASK FORCE. THE PROGRAM MIGHT BE THE VERY SAME PROGRAM USED BY THE AGENCY IN PUBLIC HEARINGS TO BRIEF THE PUBLIC. IT COULD BE VIDEOTAPED OR PRESENTED IN PERSON. READING MATERIALS MIGHT BE SUPPLIED.

NEW PARTICIPANTS MUST ALSO BE BRIEFED ON THE PURPOSE AND OPERATION OF THE TASK FORCE ITSELF. WRITTEN GUIDELINES ARE OFTEN HELPFUL IN THIS CASE, BUT MUCH CAN BE DONE THROUGH DISCUSSION BETWEEN TASK FORCE LEADERS AND INDIVIDUAL PARTICIPANTS.

TASK FORCES SHOULD CLEARLY SET OUT A WORK PLAN FOR A PERIOD OF CONCERN. SIX TO TWELVE MONTHS IS A GOOD PLANNING PERIOD. THE PLAN SHOULD BE WELL-INTEGRATED INTO THE WORK PROGRAM OF THE AGENCY ITSELF, INTO PUBLIC HEARINGS AND SPECIAL POINTS WHERE PUBLIC INPUT IS IMPORTANT.

TASK FORCES CAN TAKE A LEAD IN PUBLIC PRESENTATIONS. IN SOME CASES THE TASK FORCE CAN BEST WORK WHEN PUBLIC MEETINGS ARE HELD ON PROGRAM ISSUES WHICH FOCUS SPECIFICALLY TO TASK FORCE CONCERNS. TASK FORCE PRESENTATIONS ON THOSE ISSUES CAN LEAD OFF PUBLIC DISCUSSION. IN THE ILLINOIS COASTAL PROGRAM, FIVE TASK FORCES MADE INDIVIDUAL PRESENTATIONS WHEN PROGRAM ELEMENTS WERE BROUGHT TO PUBLIC REVIEW IN SPECIAL MEETINGS. PROGRAM ELEMENTS SUCH AS STATE-LOCAL PARTNERSHIP IN CONTROL OF THE COASTAL ZONE AND BOUNDARY OF THE ZONE WERE REVIEWED BY EACH TASK FORCE FOR IMPACT ON THEIR SUBJECT AREA (EROSION, WATER QUALITY). THESE ACTIVITIES ALSO HELPED TASK FORCES IN THEIR WORK BY FORCING CLEAR AGENDAS FOR WORK, EXPLICIT GOALS, DEADLINES FOR ACTIVITIES AND END POINTS.

EACH TASK FORCE NEEDS SOME TECHNICAL ASSISTANCE. AN AGENCY STAFF MEMBER KNOWLEDGEABLE IN THE AREA OF THE TASK FORCE CONCERN SHOULD BE ASSIGNED TO THE TASK FORCE. THIS STAFF MEMBER CAN HELP TASK FORCE MEMBERS UNDERSTAND THE PROGRAM AND TECHNICAL DATA WHERE NECESSARY AND KEEP THEIR WORK TUNED TO PROGRAM ACTIVITIES. IN ADDITION, THE STAFF MEMBER CAN SERVE AS A DIRECT CONDUIT TO THE PROGRAM OF PUBLIC INPUT. MUCH INPUT WILL BE RECEIVED IN THIS "INFORMAL" MANNER RATHER THAN THROUGH TESTIMONY, PAPERS OR FORMAL COMMENTS.

THE STAFF MEMBER WHO SERVES AS LIAISON MUST BE CAREFULLY CHOSEN, THOUGH, AND WELL

BRIEFED IN DEALING WITH CITIZENS. FOR THE MOST PART, TECHNICAL STAFF MEMBERS ARE UNACCUSTOMED TO DEALING WITH WHAT THEY CONSIDER A RELATIVELY UNEDUCATED PUBLIC. THEY MUST BE TRAINED OR SELECTED TO BE TOLERANT OF "BASIC" QUESTIONS, TO HELP PEOPLE TO UNDERSTAND TECHNICAL MATTERS, TO USE LITTLE JARGON, TO BE TEACHERS AND TO HAVE REFERENCE MATERIALS AVAILABLE WHEN NEEDED BY CITIZENS.

FEEDBACK TO CITIZENS IS IMPORTANT, TOO, AND A TRUSTING RELATIONSHIP IS CRITICAL TO FURTHER ENCOURAGEMENT OF WORK ON THE TASK FORCE.

TASK FORCES CAN OFTEN WORK CLOSELY WITH INTEREST GROUP COMMITTEES WHICH ALREADY EXIST AND INTEGRATE THEIR WORK WITH THE COMMITTEES. FOR EXAMPLE, A LOCAL CHAMBER OF COMMERCE MAY ALREADY HAVE A PORTS AND HARBORS COMMITTEE. A TASK FORCE MEMBER FROM THAT CHAMBER GROUP COULD DISCOURAGE DUPLICATION AND BUILD A CONSTRUCTIVE RELATIONSHIP BETWEEN THE CHAMBER WORK AND THAT OF THE GOVERNMENT AGENCY AND OTHER PUBLICS.

AN IDEAL TASK FORCE RELATIONSHIP SHOULD HAVE A PAID TASK FORCE LEADER: EXPENSES FULLY COVERED BY AGENCY BUDGET ITEMS, AND A CLERICAL BACKUP FROM THE GROUP SUPERVISING THE TASK FORCE. THE CLERICAL BACKUP PERSON CAN THEN ENCOURAGE PEOPLE TO ATTEND MEETINGS, ASSEMBLE NEEDED DOCUMENTS, REPORT ON MEETINGS AND OTHERWISE RELIEVE THE CHAIRMAN OF SUBSTANTIAL ADMINISTRATIVE BURDENS.

EXPERIENCE IN THE TASK FORCE HAS SHOWN THAT FACILITATED TECHNIQUES, LIKE THOSE DESCRIBED IN THE SECTION OF THIS MATERIAL ON WORKSHOPS, ARE OFTEN HELPFUL IN REDUCING THE CONSIDERABLE CONFLICT THAT EXISTS AMONG INTEREST GROUPS AND INTERESTED INDIVIDUALS SERVING ON THE TASK FORCES. LEADERS SHOULD BE TRAINED IN THOSE TECHNIQUES.

WHERE TASK FORCE MEMBERS AGREE ON RECOMMENDATIONS OR FINDINGS, THEY SHOULD PRESENT THEM, BUT ELUSIVE SEARCH FOR AGREEMENT CAN BE DEBILITATING. IT IS BETTER TO HAVE DIVERSE SUGGESTIONS EMERGE FROM THE TASK FORCE THAN TO SPEND MONTHS ON ACHIEVING COMMON AGREEMENT. COMMON AGREEMENT, TOO, MAY BE MEANINGLESS TO THE AGENCY. THE TASK FORCE IS UNREPRESENTATIVE, NOT ELECTED AND THE ACTIONS ARE NOT BINDING ON ANY LEGISLATOR, LOBBYIST, INTEREST GROUP OR INDIVIDUAL.

LIMITING TASK FORCE OPERATIONS TO PARTICULAR SUBJECT AREAS SUCH AS "LAND USE" DEPENDS ON ORGANIZATION, ISSUES, FUNDS AND GEOGRAPHICAL PROXIMITY. ONLY A FEW STATEWIDE OR REGIONWIDE AGENCIES CAN AFFORD SUPPORT FOR A MULTIPLICITY OF TASK FORCES ON DIFFERENT ISSUES.

WHERE PROBLEMS RANGE OVER A LARGE GEOGRAPHICAL AREA EITHER SUBSTANTIAL TRAVEL FUNDING IS NECESSARY OR TASK FORCES MUST BE MULTI-ISSUED AND GEOGRAPHICALLY LIMITED. A MULTI-ISSUE TASK FORCE PRESENTS A DIFFERENT SORT OF PROBLEM IN SUSTAINING INTEREST, IN ACCOMPLISHMENT, AND IN GATHERING NEEDED TECHNICAL HELP. SUCH TASK FORCES, HOWEVER, OFTEN HAVE THE ADVANTAGE OF MEMBERS KNOWING HOW TO WORK WITH OTHERS FROM PRIOR CONTACTS AND WORK OR VOLUNTEER RELATIONSHIPS.

RECOMMENDATIONS FROM TASK FORCES HAVE BEEN AS DETAILED AS TEN PAGE PAPERS, AS SUMMARY AS SINGLE LINE STATEMENTS. A ONE PAGE BRIEF HAS BEEN MOST USABLE BY AGENCIES.

THERE ARE, OF COURSE, OTHER MEANS. IN THE SEARCH FOR AN EFFECTIVE METHOD, A MOST LIKELY IMPROVEMENT SEEMS TO BE THE HALF DAY OR ONE DAY "WORKSHOP". THE TIME IS LONG ENOUGH FOR ADEQUATE UNDERSTANDING AND INPUT TO THE AGENCY, BUT NOT TOO LONG TO DISCOURAGE THE VOLUNTEER AND HIGHLY ACTIVE CITIZENS WHO SHOULD BE INVOLVED.

SUCH A WORKSHOP MUST INVOLVE SPECIFIC OBJECTIVES, AND A METHOD OF OPERATION. THIS SECTION DESCRIBES HOW ONE FORM OF THE WORKSHOP EVOLVED -- THE FACILITATED WORKSHOP.

THE OBJECTIVE OF THE FACILITATED WORKSHOP IS TO ENCOURAGE A GROUP OF CITIZENS REPRESENTING NEEDED BACKGROUNDS AND APPROACHES TO A PARTICULAR SUBJECT TO DISCUSS THE PRINCIPAL FACTS AND PROBLEMS CONCERNING THAT SUBJECT. THIS SHOULD BE DONE WITHOUT CITIZENS OR AGENCIES ENGAGING IN DEFENSIVE PROTECTION OF THEIR POSITION. THE PROCESS HAS THE POTENTIAL FOR DETAILED DEVELOPMENT OF FACTS AS WELL.

THE USE OF A FACILITATOR AND A PARTICULAR MEETING SETTING IS MEANT TO ENCOURAGE COMMUNICATION OF THE BASIS FOR A POSITION, FACT OR ISSUE. A WORKSHOP SHOULD ALSO ATTEMPT TO ISOLATE THE FACT OR ITEM PRESENTED FROM THE PROPONENT OF THAT FACT OR ITEM. ONCE PRESENTED, THE FACT OR ITEM IS DISSOCIATED FROM THE PROPONENT'S INTEREST, INTEREST GROUP, BIAS OR METHOD OF PRESENTATION. THIS INSULATION MAKES THE ENSUING DISCUSSION MORE OBJECTIVE, AND CONCLUSIONS ARE INDEPENDENT OF PARTICULAR PROPONENTS.

THE WORKSHOP SHOULD PRODUCE A LIST OF ISSUES, FACTS AND NEW PROGRAMS. THE RESULTS CAN BE USED BY INDIVIDUALS, AGENCIES AND GROUPS IN ANALYSIS AND SOLUTION OF PUBLIC POLICY PROBLEMS. THE PROCESS CAN ALSO COALESCE THE INDIVIDUALS FOR FURTHER GROUP ACTION.

THREE TYPES OF WORKSHOPS -- THERE ARE THREE BASIC KINDS OF WORKSHOPS. ONE WORKSHOP IS A PURE FACT-FINDING WORKSHOP. IT IS USED BY AN AGENCY, A GROUP, OR EVEN A BUSINESS TO DETERMINE WHAT PROBLEMS EXIST: WHAT ISSUES ARE OF CONCERN TO CITIZENS; AND WHAT PROGRAMS ARE OR ARE NOT WORKING, OR CAN OR CANNOT WORK IN THE FUTURE TO SOLVE THE PROBLEMS. THE WORKSHOP CAN SUBSTITUTE FOR AN INITIAL PUBLIC HEARING, POLL, OR SURVEY. LISTS AND DESCRIPTIONS OF PROBLEMS EMERGE FROM THE WORKSHOP TO BE USED TO STRUCTURE AND RESTRUCTURE AGENCY PROGRAMS.

ANOTHER WORKSHOP IS A FACT-DEVELOPMENT WORKSHOP. IT IS A NEW CONCEPT. IT IS USED TO IMPROVE CITIZEN FACTS AND INFORMATION. IT CAN BE USED TO PREPARE CITIZEN IDEAS FOR A SUBSEQUENT PUBLIC HEARING. THE WORKSHOP IS LIKE A SMALL SEMINAR. CITIZEN IDEAS ARE EXPANDED, IMPROVED, RELATED TO TECHNICAL STUDIES AND MADE RELEVANT TO A PARTICULAR GOVERNMENT OR PRIVATE INQUIRY. THE WORKSHOP DEVELOPS TESTIMONY OR PREPARES CITIZENS TO DEVELOP TESTIMONY, INFORMS CITIZENS OF TECHNICAL ASPECTS OF ISSUES AND DEVELOPS IMPROVED COMMUNICATION BETWEEN SCIENTIST AND CITIZEN WHICH CAN BE LATER USED IN OTHER CONTEXTS.

A THIRD TYPE OF WORKSHOP IS MUCH LIKE A PUBLIC HEARING. IT IS HERE THAT CITIZEN VIEWS ON A PROGRAM, OR ON OPERATION OF AN EXISTING PROGRAM OR ON PARTICULAR FACTS CAN BE PRESENTED TO THE AGENCY. A SUBSTANTIAL DIALOGUE IS ENCOURAGED. THE DIALOGUE IS CONTROLLED TO REDUCE TENSION AND TO GET THE FACTS BEHIND CITIZEN VIEWS. THE CONTROL IS ALSO USED TO PREVENT DEFENSIVE POSTURING BY THE AGENCY WHICH CAN OFTEN OVERWHELM, OBSCURE AND DERAIL COMMUNICATION. THE WORKSHOP CAN ALSO BE UTILIZED TO SUBSTITUTE FOR, ADD TO AND IMPROVE A CONVENTIONAL PUBLIC HEARING.

THE THIRD WORKSHOP DIFFERS FROM THE OTHER TWO TYPES IN THAT PUBLIC COMMENTS ARE MEANT CLEARLY TO EMANATE FROM THE SPEAKER.

THE FOLLOWING DISCUSSION GENERALLY DESCRIBES THE FACILITATED TECHNIQUE WHICH IS COMMON TO ALL THE WORKSHOPS.

THE FACILITATED TECHNIQUE EMERGED OUT OF METHODS IN NOMINAL GROUPS, T-GROUPS, SMALL GROUPS AND DELPHI METHODS. T-GROUPS ENCOURAGE OPEN COMMUNICATION. DELPHI METHODS USE REPEATED CONSIDERATION OF AN ISSUE TO CONVERGE ON A SOLUTION. NOMINAL GROUP TECHNIQUE INVOLVES, GENERALLY, THE GENERATION OF ISSUES OR FACTS, LISTING OF MORE FACTS AND DECISIONS MADE ON THE FACTS. THE FACILITATED TECHNIQUE ENCOURAGES PEOPLE TO SPEAK OF THE BASIC REASONS AND EXPERIENCES BEHIND THEIR PERCEPTIONS, POSITIONS, OR SUGGESTIONS.

THE TECHNIQUE IS NOT A NOMINAL GROUP TECHNIQUE AS USUALLY PRACTICED. IN SOME RESPECTS THE METHOD IS AS DECIDEDLY UNDEMOCRATIC AS NOMINAL GROUPS ARE "DEMOCRATIC". NOT ALL VIEWS ARE CONSIDERED. RELEVANCY IS IMPORTANT. IDEAS ARE "MASSAGED" TO CONFORM TO WORKSHOP NEEDS. THESE INCLUDE ISSUES UNDER DISCUSSION, THE OBJECTIVE OF THE WORKSHOP, THE MISSION OF AN AGENCY OR THE SCOPE OF THE SOLUTIONS POSSIBLE. THOSE NOT APPLICABLE ARE IMMEDIATELY DISCARDED. THE RELEVANCE TEST IS CARRIED OUT BY THE FACILITATOR AND THE GROUP. THE FACILITATOR'S ROLE, THOUGH, IS TO ENCOURAGE THE GROUP TO ANALYZE AN IDEA AND DISCARD IT WHEN NEEDED.

THE FACILITATOR ENRICHES THE GROUP PROCESS AND IS NEITHER AN UMPIRE NOR MERELY A RECORDER. THE FACILITATOR USES QUESTIONING AND PROBING TECHNIQUES TO ENCOURAGE AND DEVELOP POSITIONS AND REVEAL UNDERLYING FACTORS IN THOSE POSITIONS.

THOUGH THIS METHOD IS SIMILAR TO THE "SOCRATIC DIALOGUE", IT IS WITHOUT THE ADVERSARY APPROACH INHERENT IN THAT TECHNIQUE.

ANTECEDENTS OF THE FACILITATOR ROLE APPEAR IN LAW SCHOOL CLASSROOM TEACHING WHERE DIALOGUE IS USED TO DISSECT ATTITUDES INTO UNDERLYING ASSUMPTIONS AND FACTS. OTHER ANTECEDENTS APPEAR IN THE GRUOP PSYCHIATRY LEADER AND THE INVESTIGATIVE FACT FINDER. BUT THE QUESTIONING IS GENTLE AND PROBING, INFORMAL AND HELPFUL. SOON ALL MEMBERS OF THE GROUP UTILIZE THE TECHNIQUE. APPENDIX A PROVIDES A DESCRIPTION OF THE ACTIVITIES NORMALLY INCORPORATED INTO A FACILITATED WORKSHOP.

USE OF LOCAL COORDINATORS

AN IMPORTANT ASPECT IN THE SUCCESS OF FACILITATED WORKSHOPS, HEARINGS, MEETINGS AND TASK FORCES HAS BEEN THE UTILIZATION OF LOCAL COORDINATORS. THESE COORDINATORS WERE USED WHERE THE SPONSORING ORGANIZATION OR AGENCY WAS NOT LOCAL TO THE AREA.

THE PROBLEM OF LOCAL LIAISON IS ESPECIALLY CRITICAL IN THE GREAT LAKES REGION WHERE MOST AGENCIES AND PRIVATE ORGANIZATIONS HAVE LIMITED CONTACTS AT THE LOCAL LEVEL. THE GEOGRAPHY, POPULATION LEVEL AND POPULATION DIFFERENCES, AND JURISDICTIONAL BOUNDARIES ALMOST REQUIRE THE HELP OF A LOCAL RESIDENT.

COORDINATORS ARE CHOSEN TO:

a) Select locations for workshops and hearings, the time and date, and make all arrangements for food, rooms, flip charts, paper, registration and audio visual.

b) Develop local press and media relations and invite selected persons or the general public, and make sure a certain minimum number of people attend.

c) Serve as a bridge between the agency and citizens, lending legitimacy and local sponsorship to the activities.

COORDINATORS ARE LARGELY THE OUTREACH PART OF THE PROGRAM. ONE AGENCY (IJC) HAS SINCE ADOPTED OUTREACH BY EITHER ITS STAFF OR HIRED LOCAL COORDINATORS AS PART OF FUTURE PARTICIPATION PROGRAMS. THE USE OF A NON-STAFF MEMBER IS OFTEN MORE EFFECTIVE SINCE THE PERSON IS LOCAL, IS NOT RESTRICTED BY "AGENCY POLITICS" AND IS OFTEN WELL-SKILLED IN ORGANIZING AND ENCOURAGING PARTICIPATION.

COORDINATORS MUST BE SELECTED CAREFULLY FOR ORGANIZATIONAL SKILLS AND THE ABILITY TO GET PEOPLE TO COME TO WORKSHOPS. WHERE SELECTION WAS NOT ADEQUATE, ATTENDANCE WAS LOW, OR MAJOR INTERESTS AND INTEREST GROUPS DID NOT ATTEND.

AFFILIATION WITH AN INTEREST GROUP IS OF LITTLE MATTER IN CHOOSING COORDINATORS, THOUGH THE AGENCY SUPERVIS-NG THE COORDINATORS MUST INSURE THAT THE PROPER INTEREST GROUPS APPEAR. OFTEN A WEIGHT TO THE OPPOSITE SIDE OF THAT THE COORDINATOR IS IDENTIFIED WITH WILL INSURE THAT INTEREST GROUPS DO NOT PERCEIVE A BIAS.

COORDINATORS OFTEN COME FROM LOCAL ACTIVIST AND CIVIC GROUPS, MAY BE ON THE STAFF OF A CHAMBER OF COMMERCE, OR SEA GRANT PROGRAM, CAN BE AT A UNIVERSITY OR WITH A LOCAL GOVERNMENT AGENCY. AN IMPORTANT FACTOR IN SUCCESS HAS BEEN THE ONGOING CONCERN OF THE COORDINATOR WITH THE PROJECT, AGENCY, PROGRAM OR ISSUE AREA.

WHERE IT IS POSSIBLE, COORDINATORS SHOULD BE MADE PART OF THE PLANNING TEAM TO DEVELOP THE HEARING OR WORKSHOP FORMAT AND CONTENT. THEY SHOULD MEET WITH OTHER COORDINATORS AND WITH STAFF CARRYING OUT THE PARTICIPATION ACTIVITY AT AN EARLY DATE. SUCH MEETINGS CAN INSURE THAT LOCAL ACTIVITIES HAVE THE FORMAT TO MEET LOCAL NEEDS AND THAT LOCAL CHANGES TO MEET LOCAL NEEDS ARE MADE IN THE CONTEXT OF UNDERSTANDING THE OVERALL OBJECTIVES OF THE PROGRAM.

MANY COORDINATORS WERE PAID FOR THEIR ACTIVITIES. AND SOME CONTRIBUTED FAR MORE TIME THAN THE PAY REPRESENTED. TO SOME THIS WAS ADDITIONAL CIVIC ACTIVITY OR PROFESSIONAL WORK CONNECTED WITH THEIR JOBS.

A LOCAL STEERING COMMITTEE HAS SOMETIMES BEEN ASSEMBLED BY A COORDINATOR AS WELL. THE STEERING COMMITTEE FURTHER BROADENS THE RANGE OF INTEREST. BUT THIS METHOD SHOULD BE USED SPARINGLY AND ONLY WHERE THE ISSUES NEED THIS SPONSORSHIP TO BE ATTRACTIVE TO THE INTEREST GROUPS IN THE AREA. PITFALLS INCLUDE LACK OF FIRM LEADERSHIP IN PLANNING THE LOCAL PORTION AND THE NEED, BEFORE THE PLANNING, TO DEFUSE ANTAGONISMS BETWEEN GROUPS WHICH MAY EMERGE IN SUCH A STEERING COMMITTEE.

ACCOUNTABILITY

CITIZEN FAILURE TO PARTICIPATE IN PUBLIC HEARINGS, WORKSHOPS OR ADVISORY COMMITTEES IS OFTEN CONSIDERED INDICATIVE OF APATHY. YET, ONE CAUSE FOR LACK OF PARTICIPATION WHICH IS CLEARLY EVIDENT IN GREAT LAKES DECISIONS IS THE FAILURE OF GOVERNMENT TO CONSIDER PUBLIC SUGGESTIONS.

MANY AGENCIES FAIL TO ADAPT PROGRAM PLANNING SCHEDULES TO THE NECESSITIES OF PUBLIC PARTICIPATION. WORK IS SCHEDULED SOLELY ON THE BASIS OF TECHNICAL NEED OR AGENCY STAFF CONVENIENCE. CITIZEN PARTICIPATION, CITIZEN FACTS, ISSUES AND CONCERNS ARE NOT MADE PART OF THE PROGRAM WITHIN THE AGENCY SCHEDULE. PAPERS AND BRIEFING MATERIALS ARE SENT TO CITIZENS WITH SHORT NOTICE. HEARINGS RARELY ARE ANNOUNCED SIGNIFICANTLY IN ADVANCE. CITIZENS ARE ASKED TO RUSH TO COMMENT ON PROGRAMS. AS A RESULT, AGENCIES FIND CITIZEN SUGGESTIONS INADEQUATE AND CITIZENS HAVE LITTLE PRIDE IN THEIR WORK. EVENTUALLY CITIZENS STOP BEING CONCERNED AND AGENCIES STOP LISTENING. AGENCIES HAVE DEVELOPED A SYSTEM THAT CANNOT BE ACCOUNTABLE TO THE PUBLIC. THEY VIEW PUBLIC INPUT AS ONLY AN EXTRA, A FRILL, AN ACCESSORY TO WHAT THEY CONSIDER THE MAIN JOB -- AND THEIR SCHEDULING CLEARLY COMMUNICATES THIS TO THE PUBLIC.

SUCCESSFUL CITIZEN PARTICIPATION PROGRAMS ADAPT AGENCY TIME SCHEDULES TO ABSORB CITIZEN PARTICIPATION AND ALSO PROVIDE RESOURCES IN TIME, MONEY AND SKILLS TO INCORPORATE CITIZEN SUGGESTIONS INTO THE PROGRAM. THEY AVOID THE PROBLEM OF RECEIVING A VAULABLE CITIZEN SUGGESTION ONLY MONTHS BEFORE PROGRAM FUNDS RUN OUT OR JUST PRIOT TO THE TIME FINAL ACTION MUST BE TAKEN, LEAVING LITTLE ROOM TO INCORPORATE CITIZEN SUGGESTIONS.

EVEN WHERE TIME SCHEDULES AND RESOURCES ARE ADEQUATE, AGENCIES NEED A SYSTEM OF ACCOUNTABILITY TO CITIZEN SUGGESTIONS. STAFF MEMBERS HANDLING PARTICULAR ISSUES OR PROBLEM AREAS SHOULD HAVE CITIZEN SUGGESTIONS ROUTED TO THEM AND CONSIDERATION OF SUCH SUGGESTIONS SHOULD BE MANDATORY. OFTEN A REPORTING AND TRACKING SYSTEM SHOULD FOLLOW THE SUGGESTION THROUGH THE ADMINISTRATIVE PROCESS.

AT THE END OF THE REPORTING SYSTEM, THE CITIZEN SHOULD EITHER BE NOTIFIED WHAT HAS HAPPENED TO THE SUGGESTION, OR SUCH INFORMATION SHOULD BE AVAILABLE TO THE CITIZEN AT A SPECIFIC LOCATION.

IN ORDER TO CARRY OUT THESE OBJECTIVES, AGENCY ACTIONS WILL REQUIRE SOME CHANGES. A REEVALUATION OF PROGRAM PLANNING, COUPLED WITH INTERNAL DESIRE TO ADAPT WORK PROGRAMS TO THE NECESSITIES OF CITIZEN INPUT, CAN RECTIFY THE SITUATION. UNFORTUNATELY, VERY LITTLE HAS BEEN DONE TO DEVELOP A MANAGEMENT METHOD INCORPORATING PARTICIPATION INTO TECHNICAL WORK.

IN ONE METHOD THE AGENCY FIRST SOLICITS CITIZEN INPUT, THEN DOES THE TECHNICAL WORK, THEN PUTS THE PRODUCT BEFORE THE PUBLIC FOR COMMENT, THEN REDOES WHAT WORK NEEDS REVISING.

UNFORTUNATELY, THE METHOD IS TOO MECHANICAL AND GIVES LITTLE ATTENTION TO THE DAY-TO-DAY INTERACTION NECESSARY FOR EFFECTIVE PARTICIPATION. DEADLINES AND FISCAL YEAR FUNDING (THE NEED TO SPEND MONEY QUICKLY OR PRODUCE RESULTS FAST) OFTEN FORESHORTENS THE TIME AVAILABLE FOR CONSIDERATION OF CITIZEN INPUT TO DAYS, OR AT MOST, WEEKS, IF THE TECHNICAL WORK IS TO BE COMPLETED.

SIGNIFICANT STUDY NEEDS TO BE GIVEN MANAGEMENT OF GOVERNMENT WORK TO READILY INTEGRATE PARTICIPATION IN A WAY THAT ENCOURAGES CITIZENS TO TAKE PART IN WORKSHOPS, TASK FORCES, MEETINGS AND OTHER ACTIVITIES. IN MANY CASES, CITIZEN PARTICIPATION SHOULD COMMENCE LONG BEFORE AGENCY WORK BEGINS.

THE SECOND CAUSE OF PARTICIPATION FAILURE CAN BE REMEDIED IN ALMOST EVERY PROGRAM. THIS IS THE FAILURE TO SYSTEMATICALLY UTILIZE CITIZEN SUGGESTIONS.

WORKSHOPS ARE HELD, HEARING RECORDS PRODUCED; YET LITTLE IS DONE WITH THE RESULTING INFORMATION. IN CASES WHERE THE STAFF CONSIDERS THE INFORMATION, THERE IS NO EVIDENCE THEY DO SO. CITIZENS BECOME DISILLUSIONED WITH THEIR APPARENTLY FRUITLESS EFFORTS AND MAY SPEND LITTLE TIME IN THE FUTURE IN PARTICIPATION. THE AGENCY THEN FINDS APATHY, OR POOR SUGGESTIONS. THE BETTER PARTICIPANTS SOON RETIRE FROM THE ACTIVITY AND THE AGENCY SEES ITS CITIZEN PARTICIPATION EFFORT AS WASTED.

A SOUND ACCOUNTABILITY SYSTEM SHOULD:

1. Encourage staff members and officials to consider public suggestions through administrative routing of suggestions relevant to particular staff or officials' interests.
2. Trace citizen suggestions through all government consideration, adoption or rejection.
3. Quantify or otherwise report on the accountability of the agency and the particular individuals within the agency.
4. Permit citizens to check on their own suggestions and the effect.
5. Be readily manageable.

WITH THESE THOUGHTS IN MIND, THE BASIC GOALS OF THE SYSTEM WILL THEN REDUCE CITIZEN DISTRUST AND ACTUALLY GET THE INFORMATION INTO AGENCY ACTIVITY.

APPENDIX A

THE TECHNIQUE HAS BEEN USED ON ISSUES SUCH AS WATER QUALITY, PUBLIC ACCESS, AND ENERGY AS THEY RELATE TO THE GREAT LAKES AND THE REGION. AT LEAST 50 PERSONS ARE SPECIFICALLY INVITED TO A SESSION WHICH IS CONCERNED WITH A SPECIFIC ISSUE. A WELL-FUNCTIONING GROUP HAS 15 TO 25 PERSONS. THE INVITATION OUTLINES THE TOPICS OF DISCUSSION, THE PURPOSE OF THE SESSION, AND AN AGENDA FOR THE SESSION.

IT IS WISE TO MAKE ALL ACTIVITIES COST FREE. DIRECTIONS FOR REACHING THE LOCATION ARE INCLUDED, AS WELL AS A NOTATION THAT THE WORKSHOP AND MEALS ARE WITHOUT CHARGE. THE SPONSORING GROUPS ARE DESCRIBED. IT IS MADE CLEAR THAT THE PURPOSE OF THE WORKSHOP IS PRIMARILY TO ELICIT PARTICIPANT RESPONSE, NOT TO PROVIDE A LECTURE. A BRIEF ONE OR TWO PAGE OUTLINE OF THE TOPIC INCLUDED WITH THE LETTER HAS BEEN EFFECTIVE IN DETAILING THE ISSUE AND ENCOURAGING RELEVANCY WITHOUT FORECLOSING OR SERIOUSLY INFLUENCING THE CONTENT DISCUSSION POSSIBILITIES.

PREFERABLY EACH PERSON INVITED IS CALLED BY THE WORKSHOP SPONSOR AND ASKED WHETHER HE OR SHE WILL ATTEND. THIS HAS BEEN ESPECIALLY VALUABLE IN SECURING BUSY PERSONS WHO HAVE SOME BACKGROUND IN THE TOPIC.

PARTICIPANTS SHOULD BE SELECTED FROM A BROAD RANGE OF INTEREST GROUPS, BUT THIS, OF COURSE, IS DEPENDENT ON THE GOALS OF THE WORKSHOP. PARTICIPANTS SHOULD BE LIKELY TO HAVE POTENTIAL CONFLICTS WITH OTHERS, DIFFERENT PERSPECTIVES AND DIFFERENT OBJECTIVES ON THE SITUATION. THE GROUP SHOULD INCLUDE AT LEAST SOME ARTICULATE AND LEADERSHIP PEOPLE. ALL PERSONS SHOULD BE CAPABLE OF ADJUSTING TO THE FORMAT AND NOT ATTEMPT TO DOMINATE.

WHEN THE PARTICIPANTS ARRIVE, THEY ARE GIVEN NAME TAGS AND THE FACILITATOR INTRODUCES HIMSELF TO EACH, GREETING THEM AS IF THEY WERE GUESTS IN HIS OR HER HOME. PARTICIPANTS SIGN THEIR NAMES AND LIST ADDRESSES AND PHONE NUMBERS. THEY SHOULD LIST ANY GROUP AFFILIATIONS WHICH ARE RELATED TO THE WORKSHOP TOPIC. PARTICIPANTS SHOULD HAVE SOME SORT OF INFORMAL WELCOMINB EVENT. THEY MIGHT JOIN TOGETHER IN A MEAL, USUALLY TAKEN BUFFET STYLE OR IN COFFEE AVAILABLE AT THE TIME. THIS ENCOURAGES OPENNESS AND A MORE INFORMAL WORKSHOP. PARTICIPANTS TAKE SEATS AS THEY WISH AROUND A TABLE OR TABLES JUST LARGE ENOUGH, SOMETIMES SLIGHTLY SMALLER, THAN THE GROUP NEEDS. THE ROOM SHOULD BE SMALL AS WELL TO DEVELOP A SENSE OF CLOSENESS AND INTIMACY. THE MOST EFFECTIVE WORKSHOPS HAVE OCCURRED WHEN THE TABLE WAS NO WIDER THAN SIX FEET AND NO LONGER THAN FIFTEEN FEET. THIS IS VERY CRITICAL. IT IS IMPORTANT TO LEAVE NO GAPS BETWEEN THE TABLES. THE OPEN CIRCLE ORIENTATION TENDS TO DEVELOP HIGHLY ADVERSARY ROLES AND SHOULD BE AVOIDED.

THE FACILITATOR SITS AT ONE END, SURROUNDED BY PARTICIPANTS -- ONE OF THE GROUP, BUT SLIGHTLY DOMINANT IN LOCATION.

A BLACKBOARD, BUT PREFERABLY AN EASEL PAD (FLIP CHART) STANDS BEHIND THE FACILITATOR.

WHEN THE SESSION IS ABOUT TO BEGIN, THE FACILITATOR PASSES OUT AN AGENDA TO EACH PERSON. THE AGENDA IS CLEAR AND DISTINCT. CERTAIN ACTIVITIES BEGIN AND END AT A SPECIFIC TIME. BREAKS ARE NOTED AND EACH ACTIVITY HAS A NAME OR TITLE. THE CLOSING TIME IN THE LETTER OF INVITATION IS OBSERVED BOTH IN THE AGENDA AND IN PRACTICE.

THE CONFERENCE SPONSOR, IF NOT THE FACILITATOR, OPENS THE SESSION WITH A WELCOME AND INTRODUCES THE FACILITATOR WHO THEN DESCRIBES THE PURPOSE OF THE WORKSHOP AND WHAT IS EXPECTED OF THE GROUP IN TERMS OF LISTS OF ISSUES, NEW PROGRAMS, FACTS, OR OTHER MATTERS WHICH ARE THE OBJECTIVE OF THE SESSION.

THE FACILITATOR THEN DESCRIBES THE PROGRAM UNDER WHICH THE WORKSHOP IS SPONSORED AND CLEARLY NOTES THAT THIS IS NOT A TIME TO PUT AN AGENCY ON THE DEFENSIVE, OR TO "ULTIMATELY RESOLVE ISSUES". IT IS A PLACE TO EXPLORE ISSUES AND EXPLORE SOLUTIONS TO PROBLEMS. THE FACILITATOR MAKES IT CLEAR THAT EVERYONE'S HELP WILL BE NEEDED FOR THIS TO OCCUR. SUGGESTIONS, NOT CRITIQUES, WILL BE ENCOURAGED.

THROUGHOUT THE SESSIONS, PLANNERS AND ADMINISTRATORS OF GOVERNMENT PROGRAMS RELATED TO THE SESSIONS PARTICIPATE. THE FACILITATOR, THOUGH, IS EXTREMELY SELECTIVE IN ALLOWING THEM TO TALK OR CONTINUE, SINCE THEY MAY OFTEN DOMINATE THE DISCUSSION. EACH OF THESE PERSONS HAS BEEN TOLD BOTH BEFORE THE SESSIONS AND AGAIN IN FRONT OF THE GROUP, THAT HE OR SHE IS NOT THERE TO LECTURE, BUT TO LISTEN AND WHERE NECESSARY, CLEAR UP TECHNICAL QUESTIONS. THE PURPOSE OF THE SESSION IS TO EDUCATE OFFICIALS AS WELL.

EACH PARTICIPANT INTRODUCES HIMSELF OR HERSELF. IN SOME CASES, THE "REASON THEY ARE THERE" OR THE INTEREST GROUP REPRESENTED, MAY BE IMPORTANT TO TALK ABOUT THEN. DEPENDING ON THE ISSUE, IT MAY BE EFFECTIVE TO ALLOW SHORT SPEECHES TO GET PROBLEMS OFF PEOPLES' MINDS SO THAT THEY ARE NOT BLOCKED BY THEIR OWN PERSONAL "AGENDA". OFTEN PEOPLE WILL NOT PARTICIPATE UNTIL THEY GET A CHANCE TO TALK ABOUT THEIR PET PROBLEM, FACT, OR SOLUTION.

THE FACILITATOR BEGINS, THEN, BY ASKING WHAT THE IMPORTANT ISSUES OR PROBLEMS ARE IN THE AREA. OR IN SOME CASES HE MAY ASK FOR A CRITIQUE OF AN EXISTING LIST OR PROBLEMS. HE WORKS WITH THE GROUP FOR ABOUT ONE HOUR UNTIL THEY UNDERSTAND THE SCOPE OF THE TOPIC AND THE METHOD OF OPERATION. HE GUIDES THE DISCUSSION, REDUCES TENSION, PULLS OUT FACTS AND QUESTIONS AND PROBES TO GET THE ROOT ISSUES. ALL OF THIS IS DONE IN A GENTLE AND PLEASANT MANNER WITHOUT ADVOCACY OR ANY POSITION. THOUGH THE FACILITATOR MAY BE A STRONG ADVOCATE OF ONE POSITION IN THE ISSUES DISCUSSED, THE FACILITATOR MUST ACT AS A NEUTRAL. AFTER A FEW EXAMPLES OF FAIR QUESTIONING AND NEUTRALITY, THE GROUP IS USUALLY WILLING TO ACCEPT EVEN THE STAUNCHEST ADVOCATE IN THE FACILITATOR ROLE. QUESTIONS SHOULD BE FAIR, THE QUESTIONING GENTLE AND THE GROUP DYNAMICS WELL UNDERSTOOD.

A BREAK USUALLY FOLLOWS THIS INITIAL SESSION. IF THE GROUP HAS WARMED TO THE TOPIC AND UNDERSTANDS IT, THEY ARE THEN ASKED TO LIST TEN IMPORTANT PROBLEMS AND TEN SOLUTIONS, IF THEY HAVE TEN. IF NOT, THEN LESS OR MORE DEPENDING ON THEIR SITUATIONS.

THE GROUP IS GIVEN ABOUT FIFTEEN MINUTES FOR THE LISTING WHICH OCCURS ON A MIMEOGRAPHED FORM. THEN STARTING AT ONE CORNER OF THE TABLE EACH PARTICIPANT IS ASKED TO PICK THREE OF THE MOST IMPORTANT ITEMS FROM THE LIST. THESE ITEMS ARE FURTHER PROBED BY THE FACILITATOR AS IN THE ILLUSTRATED DISCUSSION UNTIL THE FACILITATOR IS SATISFIED THAT THE CORE IDEA IS PRESENTED. THE RESULT IS PUT INTO SHORT "HEADLINE" TYPE LISTINGS ON A FLIP CHART. THE ITEMS ARE NUMBERED. FILLED SHEETS ARE TORN OFF AND PASTED ON WALLS OF THE ROOM.

DUPLICATIONS ARE NOT ALLOWED AND PARTICIPANTS ARE LATER PERMITTED TO REFINE EARLIER STATEMENTS, OR IN SOME CASES BREAK THEM APART, PUT THEM TOGETHER OR RESTRUCTURE THEM AS THE REPORTING MOVES AROUND THE ROOM.

A LIST FOR TWENTY-FIVE PEOPLE OFTEN TAKES ABOUT TWO HOURS INCLUDING SUBSTANTIAL DISCUSSION, REFINEMENT, AND ELIMINATION OF ITEMS.

NOTE THAT ALL LISTINGS ARE NOT ACCEPTED. ONLY THE RELEVANT. EVEN THE RESPOSTEROUS MUST BE RELEVANT. LISTINGS ARE DEVELOPED AND CLARIFIED BEFORE LISTING. SHORTLY AFTER PRESENTATION BY AN INDIVIDUAL A LISTING ACQUIRES ITS OWN CONTENT, MEANING, AND MOMENTUM.

AFTER A BREAK, PARTICIPANTS ARE ASKED TO SELECT ABOUT FIVE OF THE ITEMS OR CATEGORIES THEY CONSIDER TO BE CRUCIAL AND PUT THIS LIST ON PAPER. THIS GIVES SOME INDICATION OF THOSE WHICH ALL CONSIDER TO BE IMPORTANT, BUT SATISFACTORILY DESCRIBES NO OTHER THING. IT DOES NOT REALLY RANK THE ISSUES, OR EXCLUDE ANY, BUT MERELY POINTS OUT AREAS THAT POLICY MAKERS AND ADMINISTRATORS COULD STRESS.

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